Calculation of Extreme Towline Tension During Open Ocean Towing

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Abstract

A new data base of extreme towline tensions for open ocean towing has been developed that will be incorporated into the U. S. Navy's Program of Ship Salvage Engineering (POSSE). The extreme towline tension consists of the mean towline tension and the peak dynamic tension with a .001 chance of exceedence in a single day. Mean towline tension can be estimated using methods in the U. S. Navy Towing Manual, and is calculated in the main body of POSSE. The statistics of the nonlinear dynamic tensions are determined by a numerical simulation method based on the seakeeping motion of the tug and tow. This simulation method was developed by Jerome H. Milgram.

The calculation of the statistics for the dynamic tension is computationally intensive. This requires a data base of extreme tensions (for specified tug, tow, towing speed, sea state, wave angle, and type of towline) to be developed to quickly determine peak tensions. The U. S. Navy Towing Manual has a method of estimating extreme tension. This method neglects the second-order wave induced forces that have a significant influence on the surge motions.

A revised data base of dynamic tensions was generated that will be incorperated into the POSSE program. This new data base helps tow planners to quickly analyze extreme tensions for different towing conditions, and anticipate dangerous peak tensions. This will result in safer open ocean towing evolutions.

Thesis Supervisor: Mark Welsh

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Chapter 1

Introduction

During open ocean towing, sea waves cause ship motions that lead to time dependent dynamic tensions in the towline. These dynamic tensions can exceed the mean towline tension in many situations. Tow planners and tug operators need the ability to estimate the extreme (peak dynamic plus mean) tensions to reduce the risk of towline failure.

The U. S. Navy Towing Manual (1) defines the extreme tension as the sum of the mean tension and the dynamic tension with a 0.001 chance of occurrence in a single day of towing. The Towing Manual has a method of calculating both the mean and the peak dynamic tensions. This procedure consists of calculating the mean tension and using a series of tables and graphs to determine the peak dynamic tension with a 0.001 chance of occurrence. These graphs are based on theoretical work on the nonlinear towing dynamics by Milgram, Triantafyllou, Frimm and Anagostou (2) (3). This method uses linear seakeeping theory to predict ship motions.

The analysis of the test results for an instrumented offshore tow conducted in 1989 indicated that the analytical model underpredicts the extreme tensions (Thomas (4)). The reason for the underprediction of the extreme tension is that the analytical model does not take into account the second order ship surge motion and resulting low frequency tension fluctuations. Unlike motions in heave, pitch and roll, the surge motion does not experience large hydrodynamic restoring forces. Therefore surge motions can be quite large causing large towline tensions.

The method has since been updated by Thomas (4) and Milgram (5) to include the effects of second-order surge forces due to sea waves, and add the ability to model the different sections of the towline instead of assuming constant properties over the entire length. This method uses a long term simulation to calculate the statistics of the dynamic tensions, and requires large

amounts of computer time. A run of 10,000 days requires 27 hours on a 200 MHz Pentium Pro, and 106 hours on a 60 MHz Pentium.

The purpose of this thesis is to develop a data base of extreme tensions similar to the one used in the U. S. Navy Towing Manual. This new data base is based on the revised long term towing simulation model. It includes various combinations of tug, tow, towing speed, sea state, wave angle, and towline type and length. This data base will be incorporated into the U. S. Navy's Program of Ship Salvage Engineering (POSSE).

To carry out a computer simulation a total of ten different FORTRAN based programs are used. Running the programs "manually" requires too much user interaction for the large number of towing configurations done here. To streamline the towing simulation process a batch file is used to control the different programs and slight modifications of the programs are done to standardize the input and output files.

An advance achieved in this thesis is a reduction in the computational time needed to complete a towing simulation. It is accomplished by applying a known distribution to the daily maximum dynamic tensions that are computed by the analytical model. A type I asymptotic distribution has a very good correlation to the calculated distribution, and requires significantly fewer days to be simulated. A 500 day simulation requires less than two hours to complete on a 200 MHz Pentium Pro.

Chapter 2 discusses methods to calculate mean towline tension. The mean tension calculation is not part of the model, but is an input value. The approach used in the Towing Manual and POSSE overestimates the mean tension. The largest error is due to the added resistance caused by sea state. The Towing Manual calculates this added resistance independent of the direction of the seas, resulting in a large errors for trailing seas. The calculations for resistance from locked propellers also overestimates the actual resistance.

Chapter 3 discusses the process of calculating the maximum daily dynamic tensions. A flow chart of this process is displayed in Figure 1-1. This process requires that data files containing ship geometry information and drag files containing the drag coefficients be prepared for each tug and tow prior to starting the simulation. These files are stored under the names of the ship, and are available for further use. A more detailed discussion of the individual programs, and their input and output files, is given in Appendix A.

Chapter 4 discusses the selection of cases to develop the data base, and the gathering of the required data.

Chapter 5 describes the type I asymptotic distributions, and compares it to the calculated distributions for several different cases. An analysis is also performed to determine the number of days that are required to be simulated using the type I distribution.

Chapter 6 discusses the results, the effect of the different inputs on the dynamic tension and any problems discovered that are not covered elsewhere.

Chapter 7 summarizes the conclusions reached and details future work remaining.

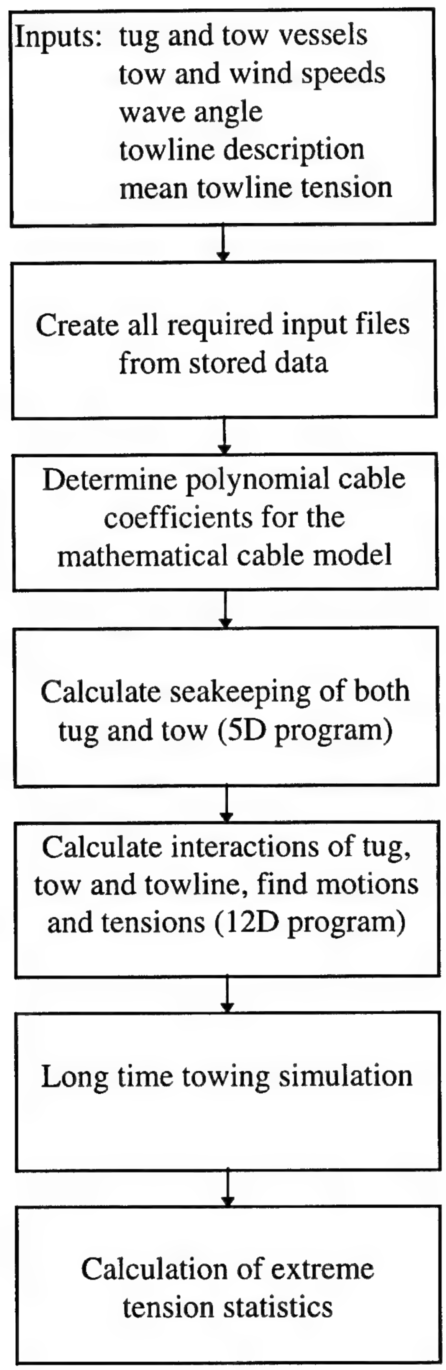

Figure 1-1: Flow Chart of Towing Simulation

Chapter 2

Mean Towline Tension

The steady state, or mean, towline tension is equal to the mean resistance of the tow plus the mean drag of the tow cable. The resistance of vessels is detailed in the Principles of Naval Architecture, Volumes II and III (6). The resistance of the tow is given by the equations:

$$R_T = R_S + R_H + R_P + R_W \tag{2.1}$$

where

R_T = steady state tow resistance

R_S = sea state or added resistance

R_H = hull resistance

R_P = propeller resistance

R_W = wind resistance

The sea state or added resistance is maximum for head seas and slightly negative for trailing seas. The added resistance is given by:

$$R_S = 2\int \left[\delta R_T(\omega_e)/\bar{\zeta}^2\right] S_\zeta(\omega_e)\, d\omega_e \tag{2.2}$$

where

$\delta R_T(\omega_e)/\bar{\zeta}^2$ = Normalized mean value of added resistance in regular waves of encounter frequency ω_e. It is often called the added resistance operator and depends on the wave angle.

$S_\zeta(\omega_e)$ = encounter variance spectrum of wave elevation

ζ = wave elevation

The hull resistance can be expressed as:

$$R_H = \tfrac{1}{2}\rho C_T A V^2 \qquad (2.3)$$

where

C_T = total drag coefficient

A = wetted surface of the hull

V = velocity

Propeller resistance depends on whether or not the propeller is installed, locked, or free spinning. For a locked propeller one approach is to calculate the flat plate drag for the equivalent disk area.

$$R_P = \tfrac{1}{2}\rho C_D A_0 V^2 \qquad (2.4)$$

where

C_D = drag coefficient = 1.17 for a bluff body (Hoerner (7))

$A_0 = \frac{\pi}{4}D^2$ = propeller disk area

D = diameter of the propeller

This approach will overestimate the propeller drag because the propeller is in the wake of the ship, and does not see the full ship velocity. This can be partially corrected by multiplying the velocity by the wake reduction factor before using it in equation (2.4).

Another approach used in the Towing Manual is to use the propeller projected area:

$$R_P = 3.737 A_P V^2 \qquad (2.5)$$

where

R_P = propeller resistance in lbs

A_P = propeller projected area in ft^2

V = velocity in kts

For a propeller with a projected area ratio of 0.72, equation (2.4) corrected for the wake effect and equation (2.5) will give identical answers. For free spinning propellers the Towing manual recommends half of the locked propeller resistance calculated above.

The wind resistance for head winds can be determined from the formula developed by D. W. Taylor:

$$R_W = 1.28 \times \tfrac{1}{2} \rho_a A_T V_R^2 \qquad (2.6)$$

where

1.28 = resistance coefficient derived from experimental data

ρ_a = density of air $= 0.00237 \dfrac{\text{lbf} \times \text{sec}^2}{\text{ft}^4}$ in English units

A_T = projected area of above water hull $\approx \tfrac{1}{2} B^2$

B = beam of the vessel

V_R = relative wind velocity = wind velocity minus ship velocity

An alternate formula for wind resistance was developed by Hughes:

$$R_W = K \rho_a A_T V_R^2 \cos\alpha \qquad (2.7)$$

where

K = nondimentional constant depending on the type of ship and wind angle, varies between .3 and .8 depending on the wind angle

α = relative wind angle

For head winds K = .6, and both the Taylor and Hughes formulas give nearly the same value.

The Towing Manual has a third method of determining the wind resistance. The equation used in the towing manual is:

$$R_W = 0.00506 C_w K A_T V_R^2 \tag{2.8}$$

where

R_W = wind resistance in lbs

C_w = wind coefficient that varies between 0.7 and 1.0

K = heading coefficient = 1.0 for head winds

A_T = projected area in ft^2

V_R = relative wind speed in kts

This formula gives nearly the same values as the previous two equations.

The towline resistance varies with the towing speed and towline type. The U. S. Navy Towing Manual lists towline resistance for different towlines, mean tensions and speeds. It also recommends that 10% of the steady state tow resistance can be used, but the size of the vessel needs to be considered before this approach is taken.

Appendix G of the U. S. Navy Towing Manual has a simplified approach to calculating the mean towline tension. This consists of a series of graphs based on ship type and displacement. This method has been incorporated into POSSE.

The Towing Manual method overestimates the mean towline tensions in several areas. First, it multiplies the hull resistance by 1.25 to account for roughness and hull fouling. Adding 25% to the calculated hull resistance is excessive. Secondly, the added resistance graph gives a value for resistance that is independent of the direction of the sea. The values may be reasonable for head seas, but greatly overestimate the resistance for beam or trailing seas. A better estimate is provided using the following formula:

$$R_S = R_{SHS}\cos(\theta) \qquad 0 < \theta < 90 \qquad (2.9)$$

$$R_S = 0 \qquad 90 < \theta < 180$$

where

R_{SHS} = added resistance from the Towing Manual

θ = angle of the seas (0 = head seas, 180 = trailing seas)

Calculated values for total resistance are compared to values obtained from POSSE in Table 2-1. These values are for LHA-1 with a tow speed of 5 kts and a wind speed of 20 kts. Added resistance is found from equation (2.2) using the RAOs from the 5D program. Hull resistance is calculated from equation (2.3) with a more reasonable 10% added to account for appendages, roughness and hull fouling. Propeller resistance is calculated from equation (2.5) and corrected by the wake fraction. Wind resistance is calculated using equation (2.6). Table 2-2 are the same calculations for a 30 kts wind speed.

Table 2-1: Total Resistance Comparison for LHA-1, 20 knots wind speed

Sea Direction	0 degrees		180 degrees	
	Calculated	POSSE	Calculated	POSSE
R_S (lbs)	33,413	9,280	0	9,280
R_H (lbs)	18,723	24,563	18,723	24,563
R_P (lbs)	19,826	24,477	19,826	24,477
R_W (lbs)	20,385	25,458	0	0
R_T (lbs)	92,347	83,778	38,549	58,320

Table 2-2: Total Resistance Comparison for LHA-1, 30 knots wind speed				
Sea Direction	0 degrees		180 degrees	
	Calculated	POSSE	Calculated	POSSE
R_S (lbs)	116,898	80,000	0	80,000
R_H (lbs)	18,723	24,563	18,723	24,563
R_P (lbs)	19,826	24,477	19,826	24,477
R_W (lbs)	39,955	49,898	0	0
R_T (lbs)	195,402	178,938	38,549	129,040

These calculations can be compared to actual tow data. Table 2-3 compares total resistance from calculated values and POSSE to a tow of a FFG-7. Case 1 is 8 kts tow speed, 12 kts wind speed and a wave angle of 177 degrees. Case 2 is 9 kts tow speed, 12 kts wind speed and a wave angle of 0 degrees. Case 3 is 8 kts tow speed, 16 kts wind speed and a wave angle of 27 degrees.

Table 2-3: Total Resistance Comparison for FFG-7									
	Case 1			Case 2			Case 3		
	Calc	POSSE	Actual	Calc	POSSE	Actual	Calc	POSSE	Actual
R_S (lbs)	0	467	---	6,087	467	---	14,954	933	---
R_H (lbs)	16,168	18,373	---	20,901	23,751	---	16,168	18,373	---
R_P (lbs)	32,934	40,659	---	41,681	51,458	---	32,934	40,659	---
R_W (lbs)	0	0	---	2,752	3,436	---	3,974	4,271	---
R_T (lbs)	49,102	59,499	40,000	71,421	79,112	55,000	68,030	64,236	55,000

At the lower wind speeds the hull and propeller damping dominate the resistance. Both models overestimate the total resistance. The propeller damping is excessive and a better model is needed to calculate this. Overall at lower wind speeds the POSSE values are reasonable.

For higher wind speeds this is not the case. The added resistance and wind resistance are much larger. The POSSE model calculates added resistance independent of the wave angle. For head seas the POSSE estimates are still reasonable, but for trailing seas POSSE adds an added resistance that should be slightly negative or zero. This greatly overestimates the total resistance.

The mean towline resistance is an input into the towing simulation model. The purpose of this thesis is to calculate the dynamic tension, and not predict mean tensions. A better model of predicting the mean tensions is needed that incorporates a more accurate method of calculating propeller resistance and added resistance. The POSSE model is used to find the mean towline tension. For the dynamic tension calculations mean tension values 15% greater and 15% less than the POSSE values are used.

Chapter 3

Dynamic Tension Statistics

3.1 Introduction

The mean towline tension depends only on the resistance of the tug and towline, but the dynamic, or time-varying, tension is much more complex. Estimation of dynamic tension requires a mathematical model of the complete towing system, and the interaction of the tug, tow and towline introduce a number of sources of nonlinearity.

This chapter will describe the towing simulation models developed by Milgram (5) that are used to calculate the dynamic tensions. This includes modeling of the towline, determining the seakeeping response of both the tug and tow, the twelve degrees of freedom interaction of both vessels, and the long time towing simulation. The entire simulation process requires several FORTRAN based programs that are controlled by a batch file and can be run on a personal computer.

3.2 Nonlinear Towline Model

The towline can be modeled as a perfectly flexible curved rod. The dynamic shallow sag equations are (Triantafyllou (8)):

$$m\frac{\partial^2 q}{\partial t^2} = \left(\overline{T}+\tilde{T}\right)\left(\alpha + \frac{\partial^2 q}{\partial s^2}\right) - b\frac{\partial q}{\partial t}\left|\frac{\partial q}{\partial t}\right| - \overline{T}\alpha \tag{3.1}$$

$$\tilde{T} = \frac{EA}{L}\left[p_0 - \alpha\int_0^L q\,ds + \frac{1}{2}\int_0^L\left(\frac{\partial q}{\partial s}\right)^2 ds\right] \tag{3.2}$$

where

A = cross-sectional area of the cable

E = Young's modulus of the cable

m = cable mass per unit length

s = Lagrangian coordinate along cable

q = normal motion distribution along cable

$\overline{T}$ = static tension

$\tilde{T}$ = dynamic tension

$b = \frac{1}{2}\rho C_D D$ = sectional drag coefficient

D = cable diameter

L = cable length

ρ = mass density of water

p_0 = sum of tangential displacements imposed at the ends

$\alpha = w/\overline{T}$ = catenary static curvature

w = cable weight per unit length

For towlines that are composed of several different sections equation (3.2) is modified (Milgram (5)):

$$\tilde{T} = \frac{p_0 + \sum_{i=1}^{N}\left[-\alpha_i \int_{L_{i-1}}^{L_i} q\,ds + \frac{1}{2}\int_{L_{i-1}}^{L_i}\left(\frac{\partial q}{\partial s}\right)^2 ds\right]}{\sum_{i=1}^{N}\frac{\Lambda_i}{(EI)_i}} \tag{3.3}$$

where

N = number of segments

Λ_I = Length of each individual section

Large amounts of computer time is required to integrate these equations, and they are therefore impractical for towing simulations. A simpler polynomial model can be used to express the dynamic tension in terms of the towline extension, ξ and the time derivative of the towline extension, $\dot{\xi}$.

$$\tilde{T}(\xi,\dot{\xi}) = \sum_{m=0}^{3}\sum_{n=0}^{3} a_{mn}\xi^{m}(t)\dot{\xi}^{n}(t) \tag{3.4}$$

$$\text{with } \begin{cases} m+n \leq 3 \\ (m,n) \neq (0,0) \end{cases}$$

$$a_{mn} = \text{coefficients}$$

The dynamic tensions for a wide-ranging set of prescribed time-varying extensions are calculated by integrating equations (3.1) and (3.3), with a constraint that the total tension (mean plus dynamic) must be greater than zero. The coefficients a_{mn} are chosen to minimize the mean square error between the numerical integration and the polynomial model.

3.3 Seakeeping of Tug and Tow

To determine the seakeeping response of the tug and tow the MIT5D Seakeeping Program is used. This program is described in the User's Manual for the 5 Degree of Freedom Seakeeping Program (9). The program was written in 1970 and uses strip theory based on the theoretical work of Salvesen, and later modified to include added resistance based on the theory of Gerritsma and Beukelman. The MIT5D program predicts the ship response in all of the degrees of freedom, except surge, in both regular and irregular waves. The input includes ship description, speed, wave angle and frequencies of interest. The 5D program uses a wave angle of 0 degrees for following seas and 180 degrees for head seas. That same convention is used in this thesis.

The towing calculations use a modified version of the 5D program. Many inputs are "hardwired" to allow a simpler input file to be used, and the output is in the format required by the 12D program. The outputs that are used in the towing simulation model are the added resistance RAO's to determine the wave induced surge damping, and the added mass, damping and wave forces for the 12D program.

3.4 Motions of Tug and Tow

The motions of the tug, tow and towline are much more interesting and complex than the motions of a single ship. Each vessel has six degrees of freedom driven by wave and towline forces, giving the total system twelve degrees of freedom. Figure 3-1 shows the geometry of the towing system.

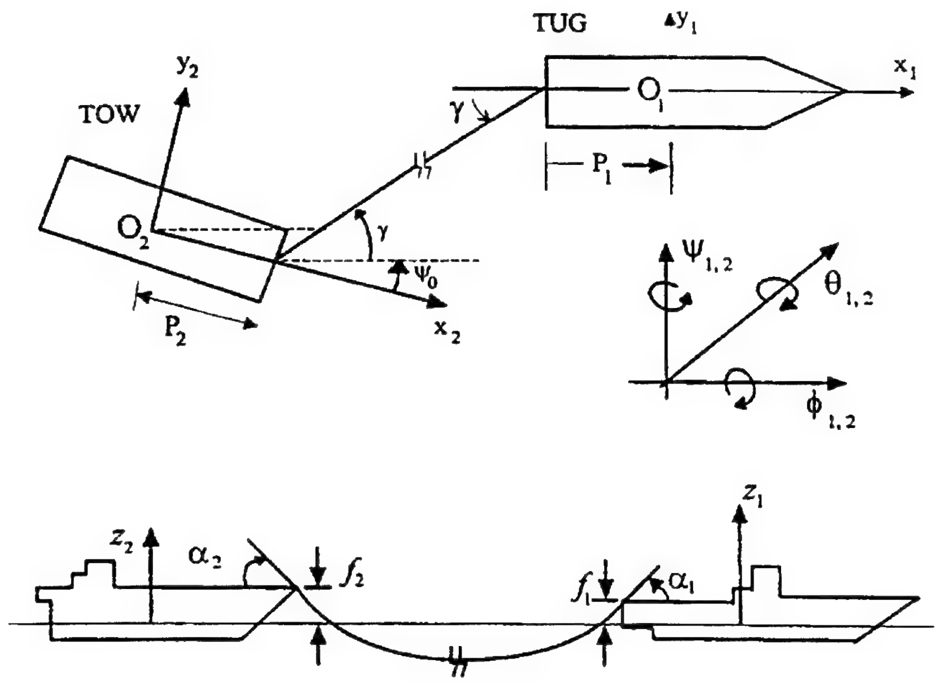

Figure 3-1: Towing Geometry

Vertical ship motions are treated as linear responses to the sea waves. The 12D program calculates all motion response operators for linear theory, but only the vertical motion and the linear part of the horizontal motion is subsequently used. The 12D equation is:

$$\mathbf{X}(\omega_e) = \left[-\omega_e^2 \mathbf{M}(\omega_e) + i\omega_e \mathbf{B}(\omega_e) + \mathbf{C}\right]^{-1} \mathbf{F}(\omega_e) \tag{3.5}$$

where

$\mathbf{X}(\omega_e)$ = 12×1 ship motion vector in the frequency domain

ω_e = encounter frequency of a wave component

$\mathbf{M}(\omega_e)$ = 12 × 12 mass plus hydrodynamic added mass matrix

$\mathbf{B}(\omega_e)$ = 12 × 12 damping matrix for the two vessels

$\mathbf{C}$ = 12 × 12 equivalent spring constant matrix

$\mathbf{F}(\omega_e)$ = 12 × 1 wave force vector

The damping matrix includes the equivalent linear damping of the towline, the frequency dependent wave radiation damping of the vessels, and the slopes of the resistance verses speed curves for the vessels. The resistance verses speed curve includes the second order wave induced damping and the propeller damping of the tug. The second order wave induced surge damping is equal to the derivative of the added resistance curve, and is covered in section 3.5. The propeller damping effect of the tug is caused by the decrease in thrust as speed is increased. This is covered in detail in section 3.6. The spring constant matrix includes the equivalent linear spring constant of the towline and the hydrodynamic restoring forces from the 5D program.

The linear wave forces can be expressed as:

$$\mathbf{F}(\omega_e) = W(\omega_e, \beta)\mathbf{H}_{\mathrm{WF}}(\omega_e, \beta) \tag{3.6}$$

where

$W(\omega_e, \beta)$ = wave component at the origin of the coordinate system

$\mathbf{H}_{\mathrm{WF}}(\omega_e, \beta)$ = 1 × 12 transfer function from wave elevation to wave forces. This includes the phase shift from the origin.

β = wave direction, 0 = trailing seas, 180 = head seas

The biggest improvement of these dynamic tension results over the data base given in the Towing Manual is the inclusion of the second order wave forces. The second order forces consist of a very low frequency component caused by the difference between the frequencies of different wave components. These forces have a very small influence on the pitch and heave

motions due to the large hydrostatic restoring forces, but the primary restoring forces for surge, sway and yaw are supplied by the towline. The cases considered here have an equilibrium configuration with the tug and tow in line. To the leading order of the towline dynamic extension used here, sway and yaw motions do not contribute. Hence we can ignore the nonlinear sway and yaw motions for these cases, but surge motion is extremely important. The surge motion can be significantly excited by the second order forces, greatly contributing to the dynamic tensions (Thomas (4) and Milgram (5)).

The towline extension is decomposed into surge and non surge components:

$$\xi(t) = \xi_{ns}(t) + \xi_s(t) \tag{3.7}$$

where

ξ = towline extension

ξ_{ns} = extension due to motions except surge

ξ_s = extension due to surge of both vessels

The approach is to solve the non surge tensions for the entire simulation time, then solve the equations of motion for the surge components. The non surge tensions are the inverse Fourier transform of Ξ_{ns}, where:

$$\Xi_{ns}(\omega_e) = \mathbf{S}_{ns}\left[-\omega_e^2\mathbf{M}(\omega_e) + i\,\omega_e\mathbf{B}(\omega_e) + \mathbf{C}\right]^{-1}\mathbf{H}_{WF}(\omega_e,\beta)W(\omega_e,\beta) \tag{3.8}$$

where

$\mathbf{S}_{ns}$ = the set of derivatives of the towline extension with respect to each of the 12 modes of motion and is given in terms of the forces, distances and angles shown in figure 3-1

$$
\mathbf{S}_{ns} = \begin{bmatrix} 0 \\ \cos\alpha_1 \sin\gamma \\ \sin\alpha_1 \\ -f_1\cos\alpha_1\sin\gamma \\ f_1\cos\alpha_1\cos\gamma + p_1\sin\alpha_1 \\ -p_1\cos\alpha_1\sin\gamma \\ 0 \\ -\cos\alpha_2\sin(\gamma+\psi_0) \\ \sin\alpha_2 \\ f_2\cos\alpha_2\sin(\gamma+\psi_0) \\ -f_2\cos\alpha_2\cos(\gamma+\psi_0) - p_2\sin\alpha_2 \\ -p_2\cos\alpha_2\sin(\gamma+\psi_0) \end{bmatrix}
$$

Milgram (5) has determined that the vertical ship motions, including their extremes, can be reasonably approximated as linear responses to the sea forces, but this is not true for the extreme towline tensions. Since the hydrodynamic forces are much larger than the towline forces, a very small error is introduced by assuming the linear towline model for ship motions. The linear towline model is used to determine the vertical ship motions.

The surge tension results from the surge motion of the tug and tow, and can be expressed as:

$$
\xi_s(t) = x_1(t)\cos\alpha_1\cos\gamma - x_7(t)\cos\alpha_2\cos(\gamma+\psi_0) \tag{3.9}
$$

The equations of surge motion are:

$$
\frac{d^2x_k}{dt^2} = \frac{1}{M_{kk}}\left[-B_{kk}\frac{dx_k}{dt} - \tilde{T}(t)S_k + f_k^1(t) + f_k^2(t)\right],\ k = 1,7 \tag{3.10}
$$

where

M_{kk} = mass plus surge added mass for the tug (k = 1) and tow (k = 7)

f_k^1 = first order surge wave force on vessel k

f_k^2 = second order slowly varying surge force

$B_{kk} = \frac{dR_k}{dV} + \frac{dT_k}{dV} + B_k^2$ = surge damping coefficient

R_k = calm water resistance of vessel k

T_k = propeller thrust of vessel k, this propeller damping term is discussed in section 3.6 and is usually zero for the tow

B_k^2 = surge damping coefficient associated with the second order wave forces discussed in section 3.4

Two problems were identified and corrected in the 12D program. Both problems were caused by higher mean tensions than have been previously used. The 12D program calculates the towline catenary by starting with a small initial angle at the tug and iterating through larger angles until a solution is reached. The fiber towlines with high mean tensions are nearly straight, and the initial starting angle needed to be decreased to reach a catenary solution. At very high mean tensions the calculated propeller damping was negative. This was caused by an unreasonable P/D ratio required to give the propeller thrust. This only occurred when the required thrust was greater than the tug could deliver. The model was made more robust by requiring a small positive propeller damping.

3.5 Second Order Wave Induced Surge Damping

The increase in added resistance as speed is increased causes a wave induced surge damping. This surge damping effects both the motions of the tug and tow, and therefore the towline tension. The wave induced surge damping coefficient is the derivative of the added resistance with the respect to speed, or the change in added resistance divided by the change in speed. The added resistance can be found from:

$$R_S = 2\int\left[\delta R_T(\omega_e)/\overline{\zeta}^2\right]S_\zeta(\omega_e)d\omega_e = 2\int RAO(\omega_e)S(\omega_e)d\omega_e \qquad (3.11)$$

where all of the terms are defined in equation (2.2)

The RAOs are calculated in the 5D program. The Pieson-Moskowitz formula is used for the sea spectrum.

$$S(\omega_e) = \frac{8.1 \times 10^{-3} g^2}{\omega_e^{\,5}} e^{-0.74\left(\frac{g}{V\omega_e}\right)^4} \tag{3.12}$$

where

S = sea spectrum

ω = frequency

g = acceleration due to gravity

V = velocity

The sea wave induced surge damping coefficient is found by running the 5D program to determine the RAOs at the tow speed and the tow speed plus one foot per second, determining the added resistance at both speeds, and dividing by the difference between the speeds. This is done for both the tug and tow.

3.6 Propeller Damping

Both the hull resistance and propeller thrust help maintain the tug at the equilibrium speed. When the ship's speed increases the hull resistance increases while the propeller thrust decreases, driving the ship back to the equilibrium speed. When speed is reduced the opposite happens, hull resistance decreases and propeller thrust increases, again driving the ship back to the equilibrium speed.

The hull damping is easy to calculate:

$$B_{hull} = \frac{d}{dV}\left(\tfrac{1}{2}\rho C_T A V^2\right) = \rho C_T A V \tag{3.13}$$

The propeller damping is more complicated. Previous models assumed constant torque and calculated the damping by allowing the propeller RPM to change. Both tugs that the Navy

currently use have diesels controlled by Woodward governors. During surges the governor works to maintain constant propeller RPM.

Propellers can be described by the following non dimensional terms:

$$J = \frac{V_A}{nD} \tag{3.14}$$

$$K_t = \frac{T}{\rho n^2 D^4} \tag{3.15}$$

$$K_q = \frac{Q}{\rho n^2 D^5} \tag{3.16}$$

where

J = advance ratio

$V_A = \dfrac{V}{1+w_f}$ = advance velocity of the propeller

V = ship's velocity

w_f = wake fraction

n = revolutions per second

D = propeller diameter

K_t = thrust coefficient

T = propeller thrust

K_q = torque coefficient

Q = torque

At constant RPM the propeller damping can be expressed as:

$$B_{propeller} = -\frac{dT}{dV} = -\frac{d\left(\rho n^2 D^4 K_t\right)}{dV} = -\rho n^2 D^4 \frac{dK_t}{dJ}\frac{dJ}{dV} = -\rho n D^3 \frac{dK_t}{dJ} \tag{3.17}$$

where

$$\frac{dJ}{dV} = \frac{1}{nD}$$

Both of the Navy tugs have two Controllable Reversible Pitch (CRP) propellers. These can operate in two different modes. In the Normal mode the throttle controls both the RPM of the engine and the pitch of the propeller. The speed and pitch are automatically balanced for the engine load. In the Split mode the engine speed and pitch are controlled independently. During towing the Split mode is usually used.

To determine dK_t/J the Wagenningen B-series propeller data is used. This data covers a standard series of propellers and the data is displayed in a series of graphs depending on the number of blades and the expanded area ratio. There is also a polynomial form of equations for K_t and K_q:

$$K_t = \sum_{s,t,u,v} C_{ctuv} J^s \left(\frac{P}{D}\right)^t \left(\frac{A_E}{A_O}\right)^u Z^v \tag{3.18}$$

$$K_q = \sum_{s,t,u,v} C_{ctuv} J^s \left(\frac{P}{D}\right)^t \left(\frac{A_E}{A_O}\right)^u Z^v \tag{3.19}$$

where

C_{stuv}, s, t, u, v = coefficients, 39 sets of coefficients for K_t and 47 sets for K_q

P = propeller pitch

A_E = expanded area ratio of the propeller

A_0 = propeller disk area

Z = number of blades

The procedure used to find the slope of the K_t and K_q curve is:

1. Assume n is 80% of the maximum operating value
2. Calculate J using equation (3.14)
3. Set the total thrust equal to the tug resistance plus the mean towline resistance
4. Divide the total thrust by two to account for both propellers
5. Calculate K_t using equation (3.15)
6. Find P/D from equation (3.18)

7. Find K_q using equation (3.19)
8. Increase the speed by 1 ft/sec and repeat the calculations
9. Find the slopes of the K_t and K_q curves by dividing their change by the change in J

One problem identified with this method occurs for extremely high mean tensions. For very high mean tensions (> 140,000 lbs) a negative damping coefficient is calculated. This occurs when the required thrust is greater than the capacity of the tug, and the model does not generate a reasonable propeller solution. There are two fairly simple solutions to this problem. The first is to limit the thrust to the rated value of the tug and the second is to set a small minimum propeller damping value. The second solution required the fewest changes to the code and no changes to the input files. An additional line was added to the code to ensure that the propeller damping was always greater than zero.

The old method of calculating propeller damping by assuming constant torque gives a propeller damping that is very close to the hull damping. The results using constant RPM gives a much higher damping. For the T-ATF towing the LHA-1 at 10 ft/sec the hull damping is 754 lbs/(ft/sec) while the propeller damping is 3,856 lbs/(ft/sec). The higher damping causes lower dynamic tensions. Due to the uncertainties in actual governor performance a conservative approach is used. The propeller damping used is the damping due to one propeller, and not the full damping. Table 3-1 shows a comparison of the dynamic tension calculations using the full damping, half damping and the damping assuming constant torque. The simulation is for a T-ATF towing LHA-1 at 5 kts with a 20 kts wind speed using 2,000 ft of wire.

Table 3-1: Comparison of Propeller Damping

Run	1	2	3
Propeller Damping	Full Damping	Half Damping	Constant Torque
Dynamic Tension	100.2 kips	100.0 kips	97.7 kips

3.7 Long Time Towing Simulation

A long time towing simulation is used to find the ship motions based on the wave forces, and to calculate the dynamic towline tensions.

$$\mathcal{L}(\omega_e) = \mathcal{F}[\zeta(t)] \tag{3.20}$$

where

$\mathcal{L}(\omega_e)$ = the Fourier transform of the wave elevation at the origin of the coordinate system of the tug

$\zeta(t)$ = wave elevation at the origin of the coordinate system of the tug

$$\mathcal{L}_B(\omega_e) = e^{\frac{i\omega R}{c_e(\omega_e)}} \mathcal{L}(\omega) \tag{3.21}$$

where

$\mathcal{L}_B(\omega_e)$ = the Fourier transform of the wave elevation at the origin of the coordinate system of the tow

$R = p_1 \cos\beta + p_2 \cos(\psi_0 + \beta) + G\cos(\beta - \gamma)$

G = horizontal distance between the origin of the coordinate system of the tug and tow

$c_e = \frac{g}{\omega} - V\cos\beta$ = apparent phase velocity

$\omega_e = \omega - \frac{V}{g}\cos\beta\omega^2$ = encounter frequency

p_1, p_2, ψ_0 and γ are defined in Figure 3-1

The Fourier coefficients are set for $\mathcal{L}$ and ζ is calculated by the use of fast Fourier transforms. The higher frequencies do not effect ship motions, therefore a cutoff frequency (ω_c) is used. The leads to values of ζ at discrete times where:

$$\delta t = \frac{\pi}{\omega_c} \tag{3.22}$$

Values for $\zeta(t)$ are periodic with a period of $N\delta t$. For the one day simulations used:

$N = 2^{16}$ = number of time steps

$\delta t = 1.31836$ sec

$\omega_c = 2.38295$ rad/sec

The values for $\mathcal{L}_j$ are found by using a deterministic spectrum. The energy in each Fourier component is set equal to the energy in the power density spectrum with which it is associated, and the phase of each spectral component is random.

$$\mathcal{L}_j = e^{i\phi_j}\sqrt{\tfrac{1}{2} S_W(\omega_e)\delta\omega_e} \tag{3.23}$$

where

ϕ_j = uniformly distributed random variable

S_W = power density spectrum

The long time towing simulation model calculates the maximum dynamic tension for a single day of towing based on the sea wave elevation and wave forces. This is repeated for a large number of days, and the statistical distribution of these maxima are used to predict the dynamic tension with a one in a thousand chance of exceedence.

Chapter 4

Statistics of Extreme Tensions

4.1 Distribution of the Dynamic Tensions

The dynamic tension calculations described in Chapter 3 give a series of random one day maximum dynamic tensions. From this data the statistical distribution of the dynamic tensions is developed.

There are two methods of determining the statistical distribution. The first is to run the simulation for a large number of days and calculate the cumulative distribution function from the output. This is done by ordering the output from smallest to largest and using the following formula:

$$F(\tilde{T}) = \frac{n}{N+1} \tag{4.1}$$

where

$F(\tilde{T})$ = cumulative distribution function = probability that the maximum dynamic tension during the time interval is less the $\tilde{T}$

$\tilde{T}$ = dynamic tension

n = 1 to N = ordered number of the maximum dynamic tension

N = total number of random dynamic tensions

For the one in a thousand dynamic tension F = 0.999.

The major disadvantage with this method is the large number of time intervals needed for the simulation to achieve the desired accuracy. One estimate for this number is:

$$N \approx \frac{5}{1-F} \tag{4.2}$$

For the one in a thousand tension (F = 0.999) this requires about 5,000 random time intervals.

Another method of calculating the statistical distribution is to match the output to a known distribution. This requires only enough random daily tensions to characterize the parameters of the distribution, and greatly decreases the computer time required to develop the extreme tensions.

The distribution of extreme values has been studied by Gumbel (10), and three asymptotic distributions have been developed. These asymptotic distributions describe the distribution of the extreme values even when the shape of the parent distribution is not known precisely. The asymptotic distributions are classified into three types based on the behavior at the tail ends of the underlying parent distribution. The type I distribution is valid when the parent distribution decays exponentially, the type II is valid for polynomial decay, and the type III is used when there is a finite upper bound.

The type I asymptotic distribution is used to describe the daily maximum dynamic tensions. The type II distribution was examined, but did not fit the output as well as the type I. The type I distribution can be described by the following formulas (11):

$$F(x) = \exp\left[-e^{-\alpha(x-u)}\right] \tag{4.3}$$

$$f(x) = \alpha e^{-\alpha(x-u)} \exp\left[-e^{-\alpha(x-u)}\right] \tag{4.4}$$

$$\mu = u + \frac{\gamma}{\alpha} \tag{4.5}$$

$$\sigma^2 = \frac{\sigma_s^2}{\alpha^2} = \frac{\pi^2}{6\alpha^2} \tag{4.6}$$

where

$F(x)$ = cumulative distribution function

x = random sample of extreme values

α = an inverse measure of dispersion of x

u = characteristic largest value of initial variate = modal value for x

$f(x)$ = probability density function

μ = mean of x

γ = 0.577216 = Euler's number

σ^2 = variance for x

σ_s^2 = variance of the parent distribution

The type I distribution is characterized by two parameters. If the mean and variance of the sample are known, all of the other points can be calculated. The procedure used to calculate the one in a thousand dynamic tension is:

1. Find the mean (μ) and variance (σ^2) of the sample
2. Calculate α from equation (4.6)
3. Calculate u from equation (4.5)
4. Find the value for the dynamic tension that corresponds to F = 0.999 using equation (4.3)

4.2 Comparison of Calculated and Type I Distributions

The first 100 cases used a simulation length of 10,000 days. A case consists of the complete simulation for a specified towing condition. The complete data base that is discussed in Chapter 6 contains the case numbers, towing conditions and the peak dynamic tensions.

Figure 4-1 is a comparison of the calculated distribution of daily maximum tensions to the type I distribution. This data is from case 1 for a T-ATF towing a LHA-1 at 5 kts. The

simulation results shows excellent agreement between the two methods of calculating the distribution.

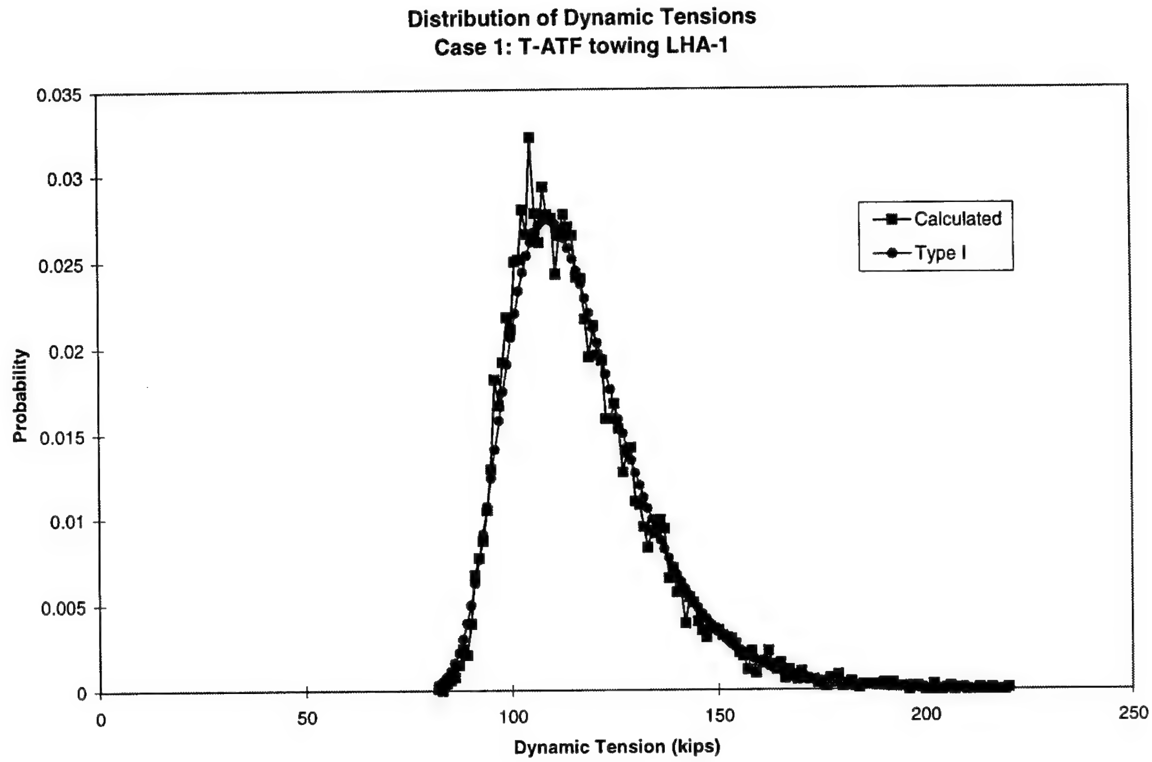

Figure 4-1: Comparison of Tension Distributions for Case 1

Tables 4-1 summarizes the differences between the dynamic tensions from the calculated and the type I distributions. Both the one in a thousand (F=0.999) and one in a hundred (F=0.99) values are compared for the first 100 cases. The calculated values are based on 10,000 day simulations. The type I values are based on the first 1,000 days of the simulation. The full comparison is shown in Appendix B. Table 4-2 compares the variability between runs of the same case using the calculated distribution and 10,000 day simulations.

Table 4-1: Comparison of Type I Distribution		
F	0.999	0.99
Max Difference (%)	27.83	22.73
Ave Difference (%)	6.38	3.38

The average difference between the calculated and the type I distributions is 6.38% for the one in a thousand dynamic tension and 3.38% for the one in a hundred dynamic tension. The 6.38% difference between the distributions is only slightly larger than the 4.99% difference between runs using the calculated distribution.

Table 4-2: Calculated Variability Between Runs			
Case Number	First Run	Second Run	Delta (%)
4	204.8	218.6	6.74
5	144.7	152.0	5.04
10	37.9	40.8	7.65
38	787.0	776.3	1.36
46	88.8	92.5	4.17
		Average	**4.99**

Even though the average difference between the calculated and type I distributions is small, there are several cases with large differences. All of the cases with greater than 10% difference between the distributions have a wave angle of 0 degrees, corresponding to trailing seas. All but one of these cases have the YRBM as the towed vessel.

The YRBM behaves differently than the other tow vessels. The YRBM is a small berthing barge with a displacement of only 650 long tons. With trailing seas and high wind speed the wave forces can overcome the drag, and the towline becomes slack. The slack towline and time varying wave forces can result in a situation where the tug and tow are moving in the opposite direction, causing the towline becomes suddenly tight, resulting in extremely high dynamic tensions.

The largest difference between the two distributions is for case 4, with 27.83%. The dynamic tension of 147.8 kips for F=0.999 using the type I distribution corresponds to F=0.992 using the calculated distribution. Figure 4-2 is a comparison of the two distributions for case 4.

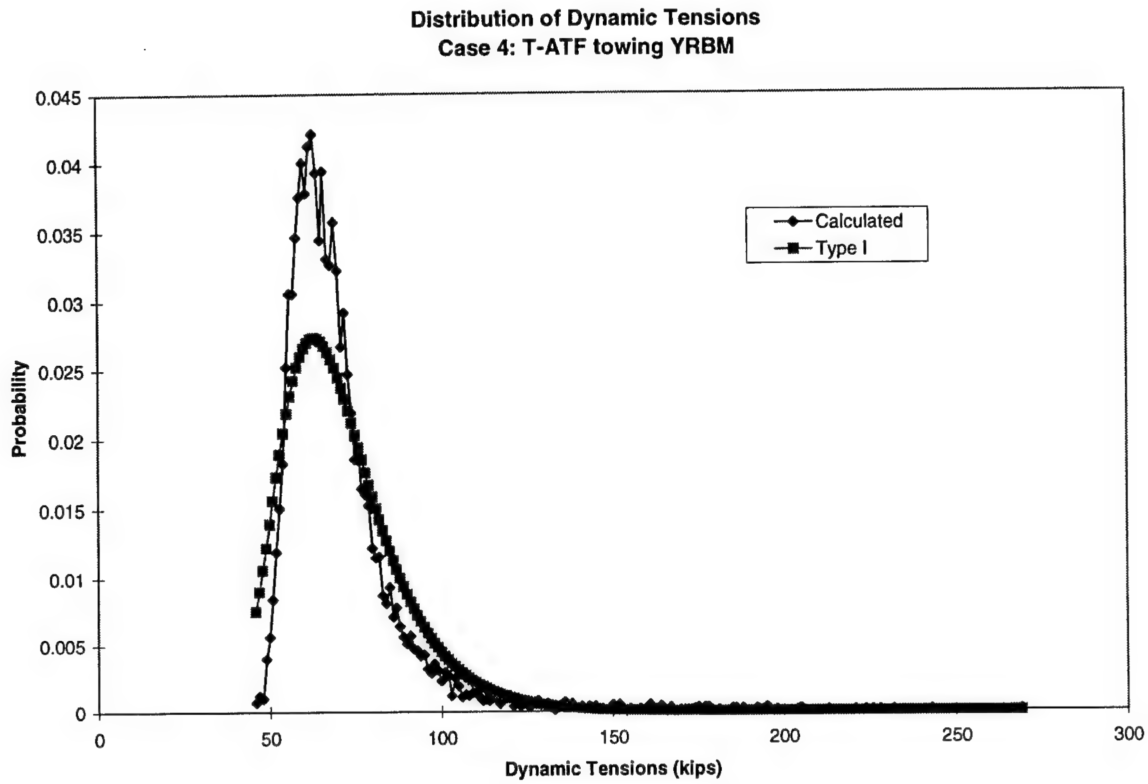

Figure 4-2: Comparison of Tension Distributions for Case 4

Figure 4-2 does not show very good agreement between the two distributions. A small number of the simulated days develop a slack towline, resulting in very high dynamic tensions as described above. These high tensions increase the standard deviation and spread out the type I distribution. The part of the curve of interest for determining the maximum dynamic tensions is the tail. While there is a large difference between the two distributions over most of the curve, there is reasonable agreement above 130 kips.

The difference between the two distributions shown in Figure 4-2 is the largest of the 100 cases compared. The problems that lead to this large difference only occur for the YRBM with trailing seas. The advantages gained by using the type I distribution outweigh the error introduced for this one tow.

Another advantage of the type I distribution is the variability between runs is smaller. Table 4-3 compares the variability between the runs of the same case using the type I distribution and 500 day simulations. The average variability is 1.22%, or one fourth the difference between runs using the calculated distribution.

Table 4-3: Type I Variability Between Runs

Case Number	First Run	Second Run	Delta (%)
145	77.2	79	2.33
238	431.9	431.3	0.14
239	468.4	463.8	0.98
281	512	514.9	0.57
300	5486.4	5485.7	0.01
318	40.7	40.7	0.00
310	443.9	442.2	0.38
339	417.6	423.8	1.48
359	121.8	123.1	1.07
361	487.2	509.5	4.58
375	86.8	92.3	6.34
431	25.3	25.5	0.79
441	508.4	507	0.28
472	147.7	147.6	0.07
494	46.9	46.6	0.64
507	200.5	206.4	2.94
617	431.7	431.6	0.02
789	202.8	204.4	0.79
867	143.7	147.1	2.37
908	129.7	130.4	0.54
980	136.3	139.0	1.98
1001	212.8	211.3	0.70
1040	597.3	595.7	0.27
1050	112.3	113.3	0.89
1089	812.1	814	0.23
1105	114.6	113.0	1.40
		Average	**1.22**

The type I distribution gives reasonable approximation of the calculated distribution. It underpredicts the dynamic tension in trailing seas, but the average difference between the two

distributions is only 1.39% greater than the average difference between runs using the calculated distribution. The use of this distribution saves a large amount of computer time and allows many more cases to be run.

4.3 Length of Simulations Required

An analysis is required to determine the number of days of simulation required to converge on a solution. The simulations only need to be long enough to properly determine the average and variance. Table 4-4 is a comparison of the peak dynamic tension for the first 100 cases using several different lengths of simulation. The peak dynamic tensions are compared to the value obtained by using the type I distribution with the full 10,000 days. The full comparison is given in Appendix B.

Table 4-4: Comparison of Various Length Runs

Number of Days	1000	500	300	100
Max Difference (%)	5.66	9.43	9.46	17.13
Ave Difference (%)	1.45	2.31	2.79	3.91

The results demonstrate simulation runs can be shortened from 10,000 days to 300 days without a significant loss of accuracy. The average difference for the 100 day runs is still very good, but several of the cases have a differences greater than 10%. The 500 day simulation is a good balance between accuracy and speed. A 500 day run can complete in under 2 hours on a 200 MHz Pentium Pro, and in 6 hours on a 60 MHz Pentium.

4.4 Summary of the Type I Distribution

The type I distribution allows the number of days simulated to be reduced from 10,000 to 500. This results in a twentyfold savings in the computational time. Additionally, reasonable results can be obtained with simulations as short as 100 days.

The average difference between the type I and calculated distributions is only 6.38%. This is only slightly larger than the 4.99% difference between runs of identical cases using the calculated distributions. The average difference between runs of identical cases using the type I distribution is only 1.22%.

The type I distribution underestimates peak dynamic tension for trailing seas. This is significant for the YRBM, but much smaller for the other tows.

The advantages of the type I distribution outweigh the disadvantages. Therefore the type I distribution is used to develop the data base of dynamic tensions.

Chapter 5

Selection of Towing Scenarios and Gathering of Data

5.1 Selection of Tugs and Tows

The tug and tow combinations are selected to provide a wide variety of tow displacements. The primary user of the data base is the U. S. Navy, therefore Navy ships are selected.

The U. S. Navy currently only has two classes of tugs that are capable of open ocean towing. They are the ARS50 and T-ATF166 classes. These two tugs are used to develop the data base of extreme tensions. Table 5-1 gives a brief summary of these tugs.

Table 5-1: U. S. Navy Tugs

Ship	Length (ft)	Displacement (lton)	Propulsion	Max Speed (knots)	SHP
ARS50	255	3282	4 Diesels 2 Screws	15	4200
T-ATF166	225	2260	2 Diesels 2 Screws	15	7200

The selection of tows need to cover a wide variety of displacements. It is anticipated that tow planners will select the tow from the data base that is the closest to their actual tow. Table 5-2 summarizes the five tows selected.

Table 5-2: Selection of Tows			
Ship	**Length** (ft)	**Displacement** (lton)	**Description**
LHA - 1	778	39,300	Amphibious Assault
AE - 26	540	18,000	Ammunition Ship
CG - 47	529	9,600	Cruiser
FFG - 7	408	3,585	Frigate
YRBM	146	650	Berthing Barge

5.2 Towing Conditions Simulated

The towing conditions simulated are based on cases provided in the Towing Manual, considerations for the total number of runs, and input from the U. S. Navy. Table 5-3 lists the different conditions simulated for each of the ten tug and tow combinations.

Table 5-3: Towing Conditions	
Tow Speeds (knots)	5 and 9
Wind Speeds (knots)	20, 30 and 35
Wave Angles (degrees)	0, 60, 120 and 180
Towlines	2000 ft - wire, 1000 ft - wire 1500 ft - fiber, 800 ft - fiber
Mean Tensions	Towing Manual Estimate ± 15%

The tow speeds in Table 5-3 are used unless the calculated mean tension is greater than 125,000 lbs. In this case, with the tension beyond the capacity of the tugs, the tow speed is reduced until a reasonable mean tension is achieved. This criteria eliminated all cases for the LHA-1 at 30 and 35 knot wind speeds, and for the AE-26 at the 35 knot wind speed.

The wind speed selected is very important in the dynamic tension calculation. The long time towing model assumes fully developed wind generated waves, therefore the wind speed specifies the sea state. Table 5-4 shows the significant wave height for the wind speeds selected. The significant wave height is the average of the highest one third of all waves, and corresponds very closely with visual estimates of wave height. For a 35 knot wind speed the significant wave height is 23 feet, and the one in a hundred wave is over 45 feet.

Table 5-4: Significant Wave Height

Wind Speed (knots)	Sea State - Beaufort Number	Significant Wave Height (ft)
20	5	7.2
30	7	16.4
35	8	22.8

The wind speed is used to define the sea spectrum, and therefore the sea forces. In cases where the seas are not fully developed calculations with a spectrum based on significant wave height and average wave period should be used.

The towline consists of a 90 feet section of chain connected to the tow in addition to the length and type of towline specified in the input. The diameter used for the chain is the diameter a circle with the same lateral drag area. Both tugs use the same fiber line, but the wire lines are slightly different for the two tugs. Table 5-5 shows the towline component characteristics.

Table 5-5: Towline Component Characteristics

Component	Diameter (in)	EA (lbs)	Weight (lbs/ft)
Chain	6.27	3.59×10^8	71.20
Fiber	4.46	3.33×10^6	1.568
Wire - T-ATF	2.25	2.07×10^7	6.744
Wire - ARS	2.25	2.96×10^7	6.400

The towing model accommodates different components in the towline. Different components in the towline allows the use of a fiber section with a wire towline, where the fiber section acts as a stretcher and reduces the peak tensions.

The expected mean tension is calculated using the procedure in the U. S. Navy Towing Manual. Runs are made at ± 15% of this value to bracket the actual towing conditions. The analysis performed in Chapter 2 demonstrate that the mean tensions calculated using the Towing Manual are too high.

To reduce the impact of any errors caused by the Towing Manual tension calculations, two procedures are used. First, simulations are done for the T-ATF towing the FFG-7 at a lower tension. The hull resistance plus one half of the propeller resistance is used for this mean tension. Only one half of the propeller resistance is used due to the problems with the Towing Manual overestimating this component of the total resistance. The lower mean tension allows the effect of the mean tension on the dynamic tension to be observed. Second, a different selection of mean tensions are used for the CG-47. The CG-47 uses the Towing Manual expected value and 60% of this value for the two mean tensions. This is a better range of tensions than used for the other tows.

5.3 Gathering of Required Data

Most of the required data was available from earlier towing analysis work. The three files required for a new tow are a file containing the towing point geometry relative to the ship, a drag file containing drag coefficients and a 5D input file containing hull geometry and stability data.

The towing point data file is the easiest to construct. This consists of the horizontal and vertical positions of the tow point. This can be estimated from ship drawings or from data from similar sized ships.

The drag coefficient file is also fairly easy to construct. Many sources of hull drag are available for Navy ships. If no other source of data is available, the Towing Manual has hull resistance graphs for Navy ships based on displacement. These graphs are used to calculate the hull resistance in POSSE. The method used to calculate the drag files for CG-47 and FFG-7 is:

1. Calculate hull resistance for various speeds using POSSE.
2. Correct these calculations for the 25% that is added in POSSE to account for roughness.
3. Find drag coefficients by using equation (2.3).

The drag coefficients calculated using POSSE can be compared to previous data for the LHA-1. The POSSE hull drag is about 20% higher than the previously available data. This is after correcting for the 25% added for roughness, and the difference is fairly constant in the speed range of 2 to 12 knots. The slopes of the two resistance curves are nearly the same, and either drag file will give the same dynamic tensions.

The 5D input file is harder to construct. This file requires hull geometry information and the location of the center of gravity. All of the required inputs for this file are discussed in Appendix A. The required information can be obtained from the ship's plans, or if the ship has been fully modeled in POSSE, all of the information is available in the detailed analysis section. POSSE is used as the data source to develop the 5D input file for CG-47. The full load condition is used to determine drafts and the location of the center of gravity.

Chapter 6

Results

6.1 Limitations

The limitations of the towing simulation process needs to be fully understood before the results are analyzed. The biggest limitation of the simulation process is the use of the Pierson-Moskowitz sea spectrum. This spectrum is a single parameter sea spectrum that assumes fully developed wind generated sea waves. It represents an asymptotic form that is reached after an extended period of steady wind with no contamination from an underlying swell. Fully developed seas for very high wind speeds are rare.

More accurate results at the higher wind speeds can be obtained by using a two parameter family, such as the Bretschneider spectrum. This spectrum allows inputs for both the wave height and period, and has the form:

$$S(\omega) = \frac{A}{\omega^5}\exp\left[-\frac{B}{\omega^4}\right] \tag{6.1}$$

where

$$\omega_M = \left[\frac{4}{5}B\right]^{1/4} = \text{modal or peak frequency}$$

$$E = \frac{A}{4B} = \text{variance} \approx H_{1/3}$$

$$H_{1/3} = \text{significant wave height}$$

The 15th International Towing Tank Conference (ITTC) recommends the use of the Bretschneider spectrum for average conditions and not fully developed seas with:

$$A = \frac{173H_{1/3}^2}{T_1^4} \tag{6.2}$$

$$B = \frac{691}{T_1^4} \tag{6.3}$$

where

$T_1 = 0.997T_M$

T_M = modal period in seconds

The use of the Bretschneider spectrum can increase the accuracy and flexibility of the towing simulations, but will also require more cases to be run to populate the data base. Due to the extremely large number of cases already required for the data base the simpler Pierson-Moskowitz sea spectrum is used. The inclusion of the Bretschneider spectrum will be considered in future improvements in the code.

Another major limitation is the accuracy of the polynomial towline equation at very high tensions. The towline simulation program calculates the cable coefficients that give the lowest root mean square difference between the shallow sag and polynomial equations. When calculating the difference between the two equations no weight is given to any tensions greater than the breaking strength of the towline.

The towline polynomial equation is not accurate above the breaking strength of the towline. This is not a problem for normal use, but can lead to problems when the data base results are evaluated. The accuracy of the very high dynamic tensions are unknown, and great care must be used when extrapolating these results.

The towline model can be updated to reduce the error in the very large dynamic tensions. For tensions greater than the breaking strength the towline is essentially straight with no catenary. The towline can be modeled as an equivalent spring where:

$$k = \frac{EA}{L} \tag{6.4}$$

where

k = spring constant with units of force/distance

E = Young's modulus

A = cross sectional area of the towline

L = length of the towline

This will give an equivalent dynamic tension for an unbroken towline. This equivalent tension is more accurate than the one generated from the polynomial equation, and will give better results when extrapolated.

The towing simulation process does not account for the Automatic Towing Machines (ATMs) that are used on many tugs. The ATMs reduce the peak dynamic tension by paying out additional towline when the tension increases and recovering the towline when the tension decreases. The response of the ATMs to rapidly varying tensions have not been evaluated. If the response time, pay out, and retrieval rates are determined they can be incorporated into the towing model. This will improve both the accuracy and flexibility of the model.

Another limitation with the simulation process is the ability to deal with multiple wave directions. Real seas have a spread of propagation directions. The method used in the model can be applied to multiple wave directions, but this will introduce second order forces due to the interaction of the waves, and also require more computer time. These second order forces are not fully understood, therefore the single direction long crested approximation is used.

The damping constant used in the 12D program accounts for the hull damping of both vessels and the propeller damping of the tug, but does not account for any propeller damping of the tow. If the tow's propeller is not removed it increases the total drag. The amount of the additional drag depends on whether the propeller is locked or free spinning, and is the same order as the hull drag. This additional drag increases the damping and reduces the dynamic tension. The problems with determining the propeller drag are discussed in Chapter 2. If a better method

of determining the propeller drag is developed it can be incorporated into the model to determine the total tug damping.

The towing simulation model is not able to handle multiple tows. Multiple tows, where one tug tows several vessels, are frequently performed, but is beyond the scope of this analysis.

The overall result of these limitations is that the towing model gives a conservative estimate for the dynamic tension.

6.2 Results

The complete data base of dynamic tensions is included in Appendix C. This data base has 1,675 different towing cases which required over 8,100 hours of computer time. A total of 15 different computers were used to generate the data base.

At least two mean tensions are used for all of the cases in the data bases. Several cases have a third mean tension, and a few have a fourth mean tension. These additional cases are included to demonstrate the effect of the mean tension, and can be used to develop a more complete data base.

Several cases have calculated dynamic tensions greater than 300 kips. These tensions are outside the bounds of the towline simulation model, and have a much reduced accuracy.

6.3 Discussion

The effect of the different variables on the dynamic tension are discussed below. The operator has only a limited ability to change most of the variables. The best methods available to the operator to reduce the peak dynamic tensions are to increase the length of the towline and change the heading to obtain a more favorable wave direction.

6.3.1 Wind Speed

The wind speed is the most important variable in determining the dynamic tension. The wind speed is used to calculate the sea spectrum, and therefore the time varying wave forces. These wave forces cause motions between the tug and tow that result in the dynamic tensions.

6.3.2 Towline Type

The type of towline is extremely important. Wire and synthetic fiber towlines behave very differently. The wire is much stiffer and heavier than the fiber, and the higher weight results in a larger catenary for the wire towline. The geometric stiffness of the catenary is much lower than the stiffness of the wire, and motion between the tug and tow straighten the catenary with very little stretching of the wire. At higher mean tensions the catenary is much smaller. This reduces the "give" of the catenary and results in much higher dynamic tensions for the same towline extension. The wire on the ARS-50 class is much stiffer than that used on the T-ATF166 class, and this results in higher dynamic tensions for the ARS-50.

The fiber towlines behave differently. The lighter weight results in a smaller catenary, and a reduced dependence on the mean tension. The reduced longitudinal stiffness leads to smaller dynamic tensions for a given extension. Sections of fiber line are commonly used with wire towlines to act as a stretcher to reduce the dynamic tensions.

The use of fiber towlines greatly reduce the dynamic tensions, but they do have some disadvantages. Fiber towlines store more energy, increasing the potential damage caused by towline failure. Additionally, the fiber towlines are much more susceptible to chafing at the fantail of the tug.

6.3.3 Towline Length

The towline length is also an important factor, and can be easily controlled by the operator. Longer towlines decrease the geometrical stiffness of the catenary and the tangential towline stiffness, resulting in lower dynamic tensions The maximum length of towline that can be used is dependent on the amount available on the tug and the depth of the water.

The effect of the towline length is greater for wire towlines as compared to fiber towlines. Additionally the length is much more important for wave directions close to 0 or 180 degrees. At 0 degrees wave angle, decreasing the wire length from 2,000 feet to 1,000 feet increases the dynamic tension by approximately a factor of four. At the same wave angle, decreasing the fiber length from 1,500 feet to 800 feet increases the dynamic tension by less than a factor of two. The response at 60 and 120 degrees are much lower for both wire and fiber towlines.

6.3.4 Wave Angle

Wave angle has an important effect on the dynamic tension. The dynamic tension is primarily determined by surge forces. At wave angles of 0 and 180 degrees the wave forces are in the surge direction, resulting in higher peak dynamic tensions.

Figure 6-1 shows the effect of wave angle on the dynamic tension for a T-ATF towing a FFG-7 with a 9 knot tow speed, 20 knot wind speed and a mean tension of 79,000 lbs. The wire towline has the maximum dynamic tension at a 0 degrees wave angle, with the tension dropping rapidly as the angle is increased. At 0 degrees the dynamic tension is 173.9 kips, but this value drops to 150.5 kips at 5 degrees. The fiber towline has the maximum dynamic tension at 180 degrees, and the change in values are more gradual.

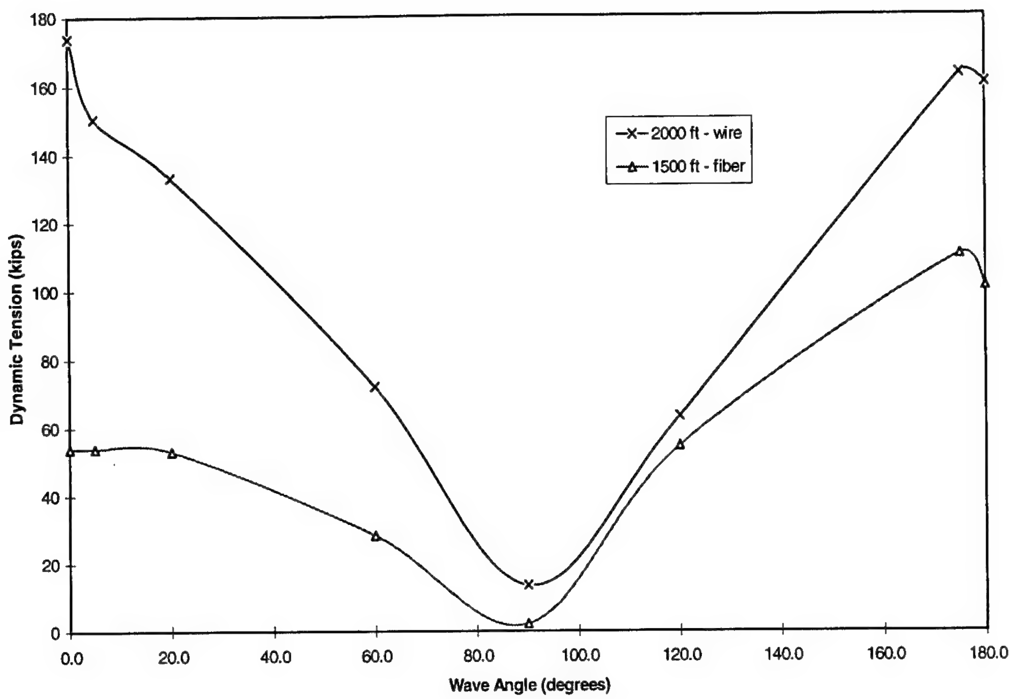

Figure 6-1: Effect of Wave Angle on Dynamic Tension

6.3.5 Mean Tension

Mean tension effects the dynamic tension primarily by its effect on the catenary. Figure 6-2 shows the effect of mean tension on the dynamic tension for a T-ATF towing a FFG-7 with a 9 knot tow speed, 20 knot wind speed and 60 degree wave angle. The difference between the wire and fiber towlines is discussed above.

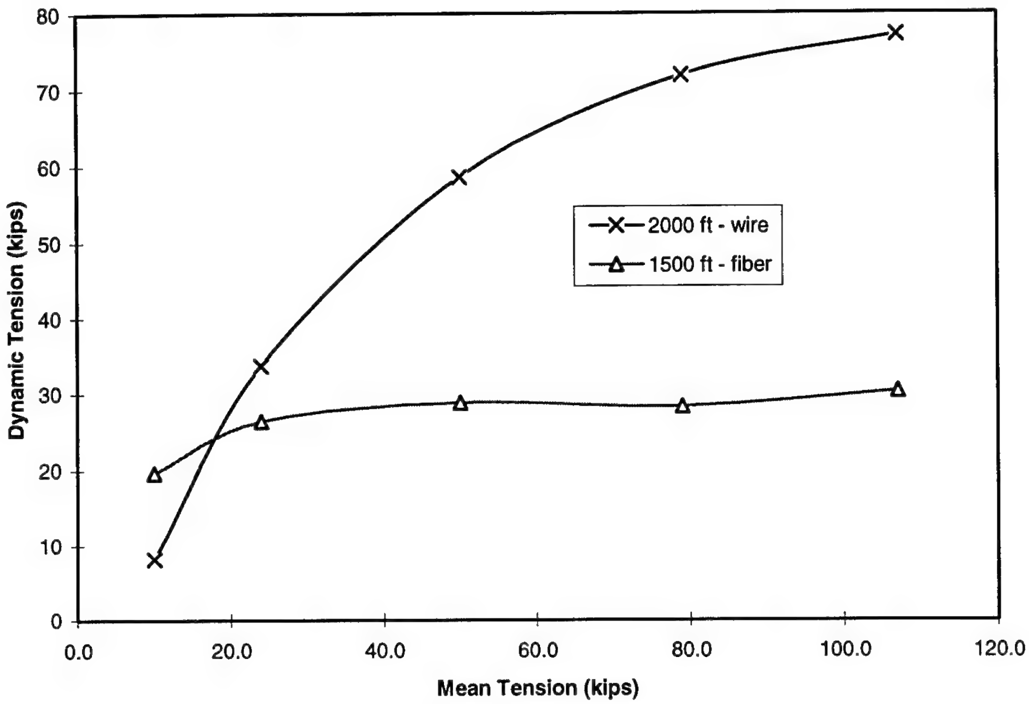

Figure 6-2: Effect of Mean Tension on Dynamic Tension

6.3.6 Tow Speed

The effect of the tow speed on the dynamic tension is small. The primary effect of the tow speed is to increase the drag of the tow, and therefore to increase the mean tension.

The tow speed for the YRBM at high wind speeds and stern seas does become very important. In these cases the surge forces on the YRBM are large enough to overcome the drag. The towline is slack for very large periods of time and can become suddenly tight when the two vessels are moving in opposite directions. This leads to extremely high dynamic tensions. When the tow speed is increased, the period that the towline is slack is reduced, and the very high dynamic tensions do not develop.

6.4 Comparison to Known Data

There is a limited amount of accurate dynamic tension measurements to compare with these predictions. The best source of data is from an instrumented submarine tow conducted in 1993 by Greg Thomas (4). This tow consisted of the USS BOLSTER (ARS-38) towing the ex-USS RAY (SSN-653), and the data was used to update the second order wave forces. Milgram (5) showed good agreement between the calculated and measured dynamic tensions. Table 6-1 compare the results from the 1993 model to the current model used in this thesis.

Table 6-1: Comparison of Dynamic Tensions for ex-USS RAY

F	1993 (kips)	Current (kips)
0.999	235	218.0
0.99	193	189.0
0.5	162	137.5

Table 6-2 compares measured daily maximum dynamic tensions to the predicted daily value for a tow of a FFG-7. Case 1 is 8 kts tow speed, 12 kts wind speed, wave angle of 177 degrees and a mean tension of 40,000 lbs. Case 2 is 9 kts tow speed, 12 kts wind speed, wave angle of 0 degrees and a mean tension of 55,000 lbs. Case 3 is 8 kts tow speed, 16 kts wind speed, wave angle of 27 degrees and a mean tension of 55,000 lbs. The measured maximum is the maximum tension reported by the operator, minus the mean tension, while the calculated value is the mode of the calculated sample.

Table 6-2: Comparison of Dynamic Tensions for FFG-7

	Case 1	Case 2	Case 3
Measured (kips)	5.0	5.0	5.0
Calculated (kips)	3.5	12.3	44.9

Table 6-2 gives a very limited comparison of measured and calculated dynamic tension. The reported maximum tension is from log readings, and may not indicate the actual daily maximum tension. The reports did not indicate if wire or fiber towlines were used, wire is assumed for the calculations. Most importantly, there is not much difference between the different tow speeds and wind speeds.

Case 1 and 2 show good agreement between the measured and calculated value. These values are within the accuracy of the instruments used and the frequency that the tensions are checked. Case 3 shows a large difference between the two values. The reason for this difference is that the seas are not fully developed for this case. The 16 knot wind speed correlates to a 5 feet significant wave height, while the reported wave height is only 2 feet. The model assumes fully developed seas, and therefore greater wave forces. This results in over-predicting dynamic tension.

Chapter 7

Conclusions

7.1 Summary

The purpose of this thesis is to automate the process of calculating towline dynamic tensions, and to generate a data base of dynamic tensions for a variety of towing conditions. The calculation of the peak dynamic tension takes approximately 2 hours for a 500 day simulation using a 200 MHz Pentium Pro computer. The data base of 1,675 simulated towing conditions is included in Appendix C. In developing this data base several problems were discovered. Many of these problems were solved, but others remain for future work.

The greatest achievement of this thesis is not the generation of the data base, but the use of the extreme value distribution. Applying the extreme value distribution to the output of the long time towing simulation allows the length of simulation to be decreased from 10,000 days to 500 days. It is also proved that simulations as short as 100 days give reasonably accurate results. Without this reduction in the required length of the simulations the data base could not be generated in a reasonable amount of time.

The reduction in the computer time required to calculate the peak dynamic tension makes it feasible to use the towing simulation programs as a planning tool for open ocean towing. The operators will still need the data base, but the tow planners can use the programs to calculate dynamic tensions for cases not covered in the data base.

It will be necessary in the future to do one additional computation for each set of towing conditions, using a lower mean tension. For each condition, this will provide three points to fit a curve of peak dynamic tension verses mean tension. This will allow the operator to determine dynamic tension for any realistic operational mean tension.

Another consideration is that all the calculations are done for fully developed seas at each wind speed. For many open ocean towing operations the seas are not fully developed. This thesis has reduced the time required to calculate the dynamic tension to less than two hours in a single processor on a high end personnel computer (PC). This translates to less than one hour on a two processor PC that are now economically available. The scope of the data base calculations should be increased. The increased data set should include a smaller average wave period associated with each wave height.

A special case, which occurs relatively often is a combination of a long swell and shorter wind driven sea. For example, this is quite common in the Pacific Ocean within 100 miles of the U. S. west coast. It is worthwhile to include some of these cases in the data base. However, because there are so many combinations of sea height, sea period, sea direction, swell height and swell direction, a decision is required whether to greatly increase the scope of the data base or to implement the fastest possible computations aboard the tow vessels.

7.2 Recommendations for Future Work

The towing simulation model gives a method of predicting dynamic tensions for open ocean towing. While the model gives reasonable results several improvements can increase the flexibility and accuracy of the process. These include:

1. Improve the mean tension calculations.
2. Determine the response of ATMs, and include this into the long time towing simulation.
3. Improve the data base by running cases with a lower mean tension.
4. Add the tow's propeller damping to the hull damping.
5. Include the option to use a Bretschneider sea spectrum.
6. Modify the towline model to include equivalent tensions above the breaking strength of the towline.

Most of these issues are discussed in more detail in Section 6.2, and are briefly described below.

The mean tension is an input into the towing simulation, and not calculated by the model. The operator can measure the mean tension and use the data base to determine the dynamic tension. However, for tow planning an accurate method of determining mean tension is needed. The current method used in the U. S. Navy Towing Manual has several shortcomings, particularly in the calculation of propeller drag and added resistance. A better method of calculating mean towline tension is desired.

The ATMs are commonly used to reduce dynamic towline tensions. The response of these machines to rapidly varying dynamic tension needs to be evaluated. After the response is quantified it can be included into the long time towing simulation model.

The data base can be improved by running more cases at lower mean tensions. This has been accomplished for the T-ATF towing a FFG-7. The third data point will allow a better curve to be fitted to the data, and a more accurate determination of the dynamic tension.

The propeller drag of the tow needs to be added to the hull drag before the hull damping is determined. The hull damping is the change in drag with respect to speed. The propeller damping is calculated separately for the tug, but not for the tow. When an accurate method of determining the propeller drag for a locked propeller is developed this can be included in the damping calculations.

Another change that can increase the flexibility of the model is to include an option to use the Bretschneider sea spectrum. This requires one additional input, but will allow both the wave height and period to be specified.

The last change that can improve the process is to change the towline model to include equivalent tensions above the breaking strength of the towline. This will result in a more reasonable value for the very high dynamic tensions.

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APPENDIX A

Towing Simulation Programs

A.1 Introduction

This appendix describes the different programs used in the towing simulation and their associated input and output files. The theory used in these programs is discussed in the main text. This section is intended to provide guidance to users.

All of the programs used in the simulation are FORTRAN based. These programs were developed over several years and modified to be used in the dynamic tension calculations. The programs run fastest when compiled under Microsoft Powerstation 4.0 and run on a Windows 95 or Windows NT machine. This combination requires less than half the computer time as compiling with Microsoft Powerstation 1.0 and running on a Windows 3.1 machine.

Most of the programs are short and require less than a minute to complete on a PC. The two exceptions are cabnexp and sapc97. Both of these programs take significant computer time. These programs are compiled using the Powerstation option of optimizing for speed. This reduces the required run time by a factor of two without any loss of accuracy. Additionally it was found that compiling the programs as .f files, instead of .for files, further reduces the time required. A 500 day simulation requires slightly under 2 hours on a Pentium Pro 200 MHz machine and approximately 4 hours on a Pentium 150 machine.

A.2 Towsim

Towsim is the batch program that controls all of the programs. The complete batch file is:

```
pretow
```

```
cabnexp
del f*.out
t3fer97
del fived.dat
del fived.dp1
copy tug.dat fived.dat
vp1
tow5d97
copy fived.??? tug.???
copy fived.adr first.adr
copy fived.dp1 fived.dat
tow5d97
copy fived.adr second.adr
copy tow.dat fived.dat
vp1
tow5d97
copy fived.??? tow.???
copy fived.adr third.adr
copy fived.dp1 fived.dat
tow5d97
copy fived.adr fourth.adr
swdauto
tow9712
sapc97
prcalcsm
calcstat
```

The required input files for a T-ATF towing a FFG-7 are listed below. Samples of these input files are given at the end of this Appendix.

t-atf.dat - ship geometry data used to make tug.dat for the 5D program

ffg7.dat - ship geometry data used to make tow.dat for the 5D program

t-atf.drg - contains speed in knots verses drag coefficient, renamed tug.drg

ffg7.drg - contains speed in knots verses drag coefficient, renamed tow.drg

t-atf.win - towline information for wire towline, used to make towline.in

t-atf.fin - towline information for fiber towline, used to make towline.in

t-atf.bld - contains tow point information and propeller information

ffg7.bld - contains tow point information

input.cas - lists the frequencies and extensions used to develop the towline cable coefficients

wavespc.12d - empty file used by 12D program

days.in - specifies the number of days to be simulated in sapc97

12dfiles.in - lists the names of all of the 12D input files

12dfiles.out - lists the names of all of the 12D output files

The process is fairly simple and the only required interface is in the first program, pretow. The program tow5d97 is run a total of four times. It is run twice for both the tug and tow with a 1 ft/sec difference in tow speed. The four added resistance output files are used to calculate the second order damping discussed in section 3.5. A brief description of each of the steps is given below.

A.3 Description of Towing Simulation Steps

Pretow

Pretow is used to generate data files based on the inputs from the user. The user specifies the towing case to be simulated and the input files required by the remaining programs are generated based on previously stored data. The program will prompt the user for the required information. This is entered using the keyboard. The inputs into the program are:

Tug Name: five letters

Tow Name: four letters

Tow Speed: knots

Wind Speed: knots

Wave Angle: degrees, 0 = trailing seas

Towline Length: feet

Towline type: f = synthetic fiber, w = wire

Mean towline Tension: pounds

The output files are:

pretow.inf - Contains the input entered by the user. This file is used in calcstat to develop the final output file called output.

wind.spd - Wind speed in knots. Used by tow9712.

tmax.in - Contains the towline breaking strength and the tension for the best fit of the polynomial towline equation. Used in t3fer97.

tow.dat/tug.dat - Ship geometry information, ship speed and wave angle. Used by tow5main.

tow.drg/tug.drg - drag coefficients for a range of speeds. The first column is speed in knots and the second is the nondimentional drag coefficient.

Towline.in - Towline information including length, diameter and Young's Modulus. Used in cabnexp and tsfer2.

Cabnexp

This program uses the towline information contained in towline.in, and the time varying cases specified by input.cas, and develops the dynamic tension based on equation 3.3. The same input.cas file is used for all of the runs with 56 different combinations of frequency and amplitude for the towline elongations. The output files are named *.out and *.fer, where * is the

case name given in input.cas. The *.out files are not used in this simulation. The *.fer files have four columns of data containing the time, displacement (ft), velocity of the displacement (ft/sec), and the dynamic tension (lbs).

Del f*.out

This DOS command deletes the 56 *.out files generated by cabnexp. These files are not used in the towing simulation.

T3fer97

The t3fer97 program calculates the nine coefficients for the polynomial cable model. The input files used are:

towline.in

tmax.in

*.fer - These are the 56 different output files from cabnexp.

The program calculates the cable coefficients that give the lowest root mean square difference between the dynamic tensions from the polynomial model and those calculated in cabnexp. Dynamic tensions above the breaking strength of the wire are eliminated prior to determining the root mean square difference.

The output files from the program are:

towline.cmp - Comparison file that contains differences and root mean square.

cable.c12 - Nine cable coefficients for the polynomial cable model. Used in tow9712.

Del fived.dat

Del fived.dp1

These two commands are used to delete 5D input files that are left over from previous runs.

Copy tug.dat fived.dat

The file containing the ship geometry data for the tug is renamed fived.dat. Fived.dat is the name used by the 5D program.

Vp1

Vp1 is a very simple program that creates a new 5D input file that is identical to fived.dat, except that the tow speed is 1 ft/sec larger. The new file that is created is named fived.dp1.

Tow5d97

Tow5d97 is the modified version of the MIT 5D Sea-keeping program described in section 3.3. This run of the 5D program is to determine the sea-keeping of the tow.

The input file is:

fived.dat - contains ship geometry data, tow speed and direction of the seas

The output files are:

fived.chk - input check, used by the 5D program

fived.adr - added resistance operators (tons/ft^2)

fived.hyd - added mass, damping and exciting force. This output file is in the 12D input format

fived.rao - heave and pitch rao's and added resistance

fived.srg - surge forces

Tow5d97 is an old FORTRAN program and will not compile on some newer FORTRAN compilers. Microsoft Powerstation 1.0 was used to compile the executable used to develop the data base, but Lahey F77 can also be used. The Powerstation and Lahey versions give slightly different values, but the difference is not significant.

Copy fived.??? Tug.???
Copy fived.adr first.adr

All of the 5D input and output files are saved under the name tug. The old 5D files will be overwritten in later steps. The added resistance file will be used by swdauto to calculate the wave induced surge damping.

Copy fived.dp1 fived.dat
Tow5d97
Copy fived.adr second.adr

The 5D program is run a second time for the tug with 1 ft/sec added to the towing speed. The added resistance file is saved for use by swdauto.

Copy tow.dat fived.dat
Vp1
Tow5d97
Copy fived.??? Tow.???
Copy fived.adr third.adr

Copy fived.dp1 fived.dat

Tow5d97

Copy fived.adr fourth.adr

The above process is repeated for the tow.

Swdauto

This program calculates the wave induced surge damping by the method described in section 3.5. The added resistance RAO files from 5D are used to calculate added resistance at two different speeds. The surge damping is the slope of the added resistance curve, and is simply equal to the difference between the two resistance's. The surge damping is calculated for both the tug and tow.

The input files are:

first.adr - added resistance RAO for tug
second.adr - added resistance RAO for tug with 1 ft/sec added to tow speed
third.adr - added resistance RAO for tow
fourth.adr - added resistance RAO for tow with 1 ft/sec added to tow speed

The output file is:

windamp.12d - surge damping for tug and tow. Used in tow9712.

Tow9712

This is the 12D program that is described in section 3.4.

The input files are:

12files.in - lists the names of the input files

12files.out - lists the names of the output files

runinf.dat - general parameters for 12d run

tug.hyd - tug added mass, damping and wave forces, tow5d97 output

tow.hyd - tow added mass, damping and wave forces, tow5d97 output

tug.drg - tug resistance curve

tow.drg - tow resistance curve

cable.c12 - polynomial cable coefficient file, t3fer97 output

wavespc.12d - wave spectrum file, not used

winddamp.12d - wind speed and wave induced surge damping coefficient, swdauto output

The output files are:

motions.12d - 12d selected motion RAOs and responses

tension.12d - tension response

runout.12d - general information and run "book keeping"

output.12d - output file with elongation spectral moments

simaux.dat - output for J.M. surge simulation program

surgefk.dat - tug and tow surge Froude Krylov Force (lbs) [Real,Imag]

sop.dat - tug and tow added resistance operators (lbs/ft2)

SAPC97

Sapc97 is the long time towing simulation program described in section 3.7. Sea wave forces are calculated using a Pieson-Moskowitz spectrum with a random phase. The program calculates the maximum dynamic tension for a single day of towing. It repeats the process with a new random phase for the number of days specified in the file days.in. The program adds 10 to

the number of days specified to ensure at least 10 days are simulated. For a 500 day simulation 510 days are actually simulated.

The input files are:

The input and output files from tow9712

days.in - specifies the number of days to simulate

The output file is:

maxima.out - gives the daily maximum tension in kips

Prcalcsm

Prcalcsm reorders all of the maximum tensions from largest to smallest and calculates the distribution similar to equation 4.1. Instead of calculating the cumulative distribution function, F, it calculates the chance of exceedence, or 1-F. This is the old method of calculating the distribution, but the file containing the list of dynamic tensions in descending order is still very useful.

The input files are:

maxima.out - from sapc97

The output files are:

final.out - contains the calculated distribution, no longer a useful file

problog - contains the tensions in descending order, this is a very useful file

calcstat

This is the final program in the towing simulation process. It finds the mean and variance of the daily dynamic tensions and calculates the distribution by the method outlined in section 4.1. The input information entered by the user in pretow is retrieved and included in the output file. A sample of the output file is included in the next section.

The input files are:

pretow.inf
towline.in
maxima.out

The output file is:

output: contains the information for the run, a sample output file is given below

```
t-atf     ffg7
Tow Speed =   5.00 knots    Wind Speed =   35.00 knots
Wave Angle =   60.00    Towline Length = 1500. ft
fiber
Mean Tension =  15000.00 lbs
Average =   41.06  variance =   10.80
.001 probability =   57.27
```

The process of evaluating the runs is fairly simple. All of the required output data is contained in the file output. The file problog provides a reasonableness check on the peak dynamic tension. A quick check is done to ensure all of the programs ran by checking the date

and time that the output files were created. One final check that was performed after most runs is to rerun tow9712 and check for error messages.

A.4 Sample Input Files

This section has samples and descriptions of the required input files. It's purpose is to assist the user in developing new input files required to run additional tug and tow combinations. The input files required are listed in section B.1. A new tow requires three new files while a new tug requires five new files. The two additional files for the tug contain data for the wire and fiber towlines. Listed below are the input files required for the T-ATF 166 class tug.

t-atf.dat: contains the 5D input data

```
TATF TUG
 18  25   1   1   1
.6357  195.  42.  15.   2.30   3.00  5.00
 48.75  16.80  48.75   .00  11200.
 97.50    .00    .00  .0000   .00
 87.75  12.00  12.83  .5000  -3.18
 78.00  21.00  15.00  .5936  -3.56
 68.25  28.33  15.00  .6723  -6.10
 58.50  34.00  15.00  .7206  -6.50
 48.75  38.34  15.00  .7849  -7.02
 39.00  40.84  15.00  .8276  -7.10
 19.50  42.00  15.00  .8596  -7.45
   .00  42.00  15.00  .8596  -7.45
-19.50  42.00  15.00  .8610  -7.42
-39.00  42.00  14.75  .8590  -7.14
-48.75  42.00  13.83  .8514  -7.06
-58.50  42.00  12.00  .8420  -6.09
```

-68.25	42.00	9.50	.8058	-4.90
-78.00	41.66	6.92	.7981	-3.18
-87.75	40.34	4.75	.7909	-2.19
-97.50	37.00	3.00	.7736	-1.40
-104.00	.00	.00	.0000	.00

12.67

160.00

.05 .10 .15 .20 .30 .40 .50 .60 .70

.80 .90 1.00 1.10 1.20 1.25 1.30 1.35

1.40 1.45 1.50 1.60 1.70 1.80 1.90 2.00

Line 1: NAME

NAME: text identifying run

Line 2: NSTA,NROMS,NENC,NVL,NSP

NSTA: number of stations

NROMS: number of frequencies in rad/sec.

NENC: number of heading angles

NVL: number of ship speeds in ft/sec.

NSP: 0 for even station spacing, 1 for uneven station spacing

Line 3: CB,XLBP,BEAM,DRAFT,XCG,VCG,GM

CB: block coefficient

XLPB: length between perpendiculars (feet)

BEAM: midship beam (feet)

DRAFT: midship draft (feet)

XCG: long. center of gravity measured from midships (positive fwd/feet)

VCG: vert. center of gravity measured from waterline

(positive up/feet)

GM: metacentric height (feet)

Line 4: RYY,RXX,RZZ,XZI,WSURFA

RYY: radius of gyration about y-axis (feet)

RXX: radius of gyration about x-axis (feet)

RZZ: radius of gyration about z-axis (feet)

XZI: mass moment of inertia about x-z axis (ton/feet2)

WSURFA: wetted surface (feet^2)

Line 5-22: (XI(I),YM(I),ZM(I),SIGMA(I),ZCB(I),I=1,NSTA)

Section properties, from i=1 (forwardmost) to i=NSTA (aftmost)

XI: distance to station "i" measured from midships, positive fwd (feet)

YM: full waterline beam at section "i" (feet)

ZM: draft at station "i"

SIGMA: area coefficient - Section Area / (Beam*Draft)

ZCB: centroid of section "i" measured from waterline (positive up)

Line 23: (UOB(N),N=1,NVL)

UOB: NVL ship speeds (feet/sec), will be changed by pretow

Line 24: (BETA(M),M=1,NENC)

BETA: NENC wave headings (degrees) in ascending order, will be changed by pretow

Line 25-28: (OMEGA(L),L=1,NROMS)

OMEGA: NROMS wave frequencies (rad/sec)

t-atf.drg: drag information

2.0	2.658E-3
3.0	2.69E-3
4.0	2.78E-3
5.0	2.905E-3
6.0	3.028E-3
7.0	3.167E-3
8.0	3.312E-3
9.0	3.447E-3
10.0	3.77E-3
11.0	4.0E-3
12.0	4.634E-3

The first column is speed in knots while the second column is the drag coefficients.

t-atf.bld: tow point and propeller data

30.0 6.0

9.0

204.3

Line 1: ALT, FBT

ALT = Long. distance from Tugs LCG to Tugs tow point

FBT = Freeboard at Tugs tow point

Line 2: D

D = Prop Diameter

Line 3: RPM

RPM = 90 % of normal operational RPM

Lines 2 and 3 are not required for the tow.

t-atf.win \ t-atf.fin: towline information, w = wire and f = fiber, not required for tow

```
3 50000.  1.0
100  90.0 3.59e8 0.5225 71.2
200 750.  2.07e7 .1880 6.744
200 750.  2.07e7 .1880 6.744
```

Line 1: m, tmean, cd

m: number of cable sections

tmean: mean towline tension, will be changed by pretow

cd : drag coefficient of the towline

Line 2-4: nsg, sl, EA, diam, w

nsg: number of segments for the section

sl: length

EA: stiffness, lbs

diam: diameter, lbs

w: weight per unit length, lbs/ft

APPENDIX B

Comparisons for the Type I Distribution

Table B-1 and B-2 compare the dynamic tensions, in kips, from the calculated and the type I distribution. Both the one in a thousand (F=0.999) and one in a hundred (F=0.99) values are compared for the first 100 runs. The calculated values are based on 10,000 day simulations. The type I values are based on the first 1,000 days of the simulation.

Table B-1. Comparison of Dynamic Tensions F = 0.999											
Run	**Calc**	**Type I**	**Delta (%)**	**Run**	**Calc**	**Type I**	**Delta (%)**	**Run**	**Calc**	**Type I**	**Delta (%)**
1	202.0	201.8	0.10	35	558.5	480.3	14.00	69	132.1	129.7	1.82
2	55.3	54.4	1.63	36	20.6	18.9	8.25	70	64.8	66.7	2.93
3	38.1	37.9	0.52	37	174	148.3	14.77	71	262.5	273	4.00
4	204.8	147.8	27.83	38	784.1	812.2	3.58	72	87.5	66.9	23.54
5	144.7	134.3	7.19	39	125.6	137.3	9.32	73	137.6	142.7	3.71
6	9.3	8.8	5.38	40	59.1	63.7	7.78	74	117.6	122.6	4.25
7	23.6	17.2	27.12	41	149.3	135.2	9.44	75	42	43.8	4.29
8	9.7	9.6	1.03	42	20.2	19.7	2.48	76	100	111.8	11.80
9	218.6	196.7	10.02	43	55.7	55.1	1.08	77	19.9	21.8	9.55
10	37.9	31.7	16.36	44	396.3	334.4	15.62	78	77.9	80.1	2.82
11	79.2	86.6	9.34	45	127.6	118.3	7.29	79	29.5	30	1.69
12	140.3	156	11.19	46	88.6	64.0	27.77	80	111.4	117.4	5.39
13	58.3	45.6	21.78	47	18.8	17.9	4.79	81	39.8	36.8	7.54
14	81	82.3	1.60	48	16.1	16.2	0.62	82	52.5	53.1	1.14
15	25	26.3	5.20	49	114.1	112.4	1.49	83	75.4	76.3	1.19
16	57.1	55.2	3.33	50	217.8	208.7	4.18	84	73.9	74.2	0.41
17	414.7	376.9	9.12	51	93.6	80.6	13.89	85	30.7	30.5	0.65
18	211.4	160.6	24.03	52	257.6	270.6	5.05	86	73.9	73	1.22
19	38.8	38.8	0.00	53	4	4.6	15.00	87	61.5	64.5	4.88
20	58.8	61.2	4.08	54	96	96.4	0.42	88	77.7	73.1	5.92
21	138.1	135.5	1.88	55	3.9	3.8	2.56	89	24.6	26	5.69
22	22.9	16.6	27.51	56	94.6	98.3	3.91	90	74.2	76.6	3.23
23	800.6	841.2	5.07	57	313	325.7	4.06	91	689.9	735.8	6.65
24	26.3	26.1	0.76	58	47.6	48.5	1.89	92	30.4	28.4	6.58
25	9.8	9.5	3.06	59	12.1	11.4	5.79	93	344.4	358.1	3.98
26	15.8	16.7	5.70	60	50.5	51.8	2.57	94	114.9	120.9	5.22
27	438	454	3.65	61	31.6	33.2	5.06	95	172.2	178.2	3.48
28	138	131.5	4.71	62	45.8	49.6	8.30	96	55.1	59.2	7.44
29	211.5	214.1	1.23	63	603.5	593	1.74	97	306.9	301.7	1.69
30	10.9	11	0.92	64	88.6	97	9.48	98	64.8	64.8	0.00
31	17.9	18.6	3.91	65	13.9	14.2	2.16	99	1176	1134.8	3.50
32	35.2	35.2	0.00	66	365.1	321.1	12.05	100	60.8	63.4	4.28
33	569.2	575.3	1.07	67	220.9	232.3	5.16				
34	371.9	376.5	1.24	68	83.6	86.9	3.95	**Ave**			**6.38**

Table B-2. Comparison of Dynamic Tensions F = 0.99

Run	Calc	Type I	Delta (%)	Run	Calc	Type I	Delta (%)	Run	Calc	Type I	Delta (%)
1	172.3	170.8	0.87	35	422.3	376.1	10.94	69	116.1	115	0.95
2	49.5	47.7	3.64	36	15.7	15.8	0.64	70	59.9	59.9	0.00
3	32.6	32.2	1.23	37	145.1	124.5	14.20	71	238.2	239.1	0.38
4	142	125	11.97	38	712.7	714.6	0.27	72	67	56.8	15.22
5	114.5	113.7	0.70	39	110.5	110.9	0.36	73	126.5	126.8	0.24
6	7.9	7.6	3.80	40	56.4	55.2	2.13	74	117.5	120.2	2.30
7	16.9	14.8	12.43	41	114.8	110.7	3.57	75	37.8	37.9	0.26
8	8.6	8.4	2.33	42	17.5	16	8.57	76	94.5	99	4.76
9	177.4	164.9	7.05	43	47.9	47.5	0.84	77	18.9	18.1	4.23
10	27.9	27.9	0.00	44	278.4	271.3	2.55	78	70.6	69.6	1.42
11	73.1	74.2	1.50	45	103.1	104	0.87	79	26.5	25.8	2.64
12	127.2	127	0.16	46	60.7	46.9	22.73	80	102.5	104.4	1.85
13	43.7	36	17.62	47	15.7	14.9	5.10	81	32.4	30.8	4.94
14	70.6	69.7	1.27	48	14.2	14.1	0.70	82	47.2	46.8	0.85
15	22.9	23	0.44	49	98.2	94.8	3.46	83	66.2	65.9	0.45
16	48	46.4	3.33	50	180.9	175.1	3.21	84	66.5	64.1	3.61
17	346.2	313.6	9.42	51	73.7	63	14.52	85	25.9	25.5	1.54
18	142	123.6	12.96	52	219.8	222.6	1.27	86	66.1	64.6	2.27
19	33.2	33.2	0.00	53	3.6	3.6	0.00	87	57.3	53.5	6.63
20	50	50.7	1.40	54	88.7	81.2	8.46	88	61.8	63.4	2.59
21	124.5	115.5	7.23	55	3.2	3.3	3.12	89	22.1	22.3	0.90
22	16.5	13.7	16.97	56	86	87.6	1.86	90	64.3	64.9	0.93
23	759.9	774	1.86	57	285	288	1.05	91	638.4	644.8	1.00
24	22.7	22.6	0.44	58	39.7	39.6	0.25	92	24.7	24.3	1.62
25	8.5	8.2	3.53	59	10.5	10	4.76	93	314.2	312.3	0.60
26	14	14.1	0.71	60	46.5	46.7	0.43	94	104.6	106	1.34
27	404.1	409.9	1.44	61	27.7	28	1.08	95	157.1	158	0.57
28	117	114.5	2.14	62	43.4	43.8	0.92	96	51.8	52.5	1.35
29	183.8	184.2	0.22	63	520.7	523.5	0.54	97	262.1	261.3	0.31
30	9.8	9.7	1.02	64	83.2	84.5	1.56	98	56.3	56.8	0.89
31	15.5	15.5	0.00	65	12.6	12.6	0.00	99	1007	1001.9	0.54
32	31.6	30.7	2.85	66	310.8	256.4	17.50	100	55	54.6	0.73
33	516	517.1	0.21	67	196.7	198.6	0.97				
34	326.6	328.4	0.55	68	76.8	76.6	0.26	**Ave**			**3.38**

Table B-3 is a comparison of the peak dynamic tension for the first 100 runs using the type I distribution with several different lengths of simulation. The peak dynamic tension is compared to the value obtained by using the type I distribution with the full 10,000 days. These results are discussed in section 4.2.

Table B-3. Comparison for Different Length Simulations

Run	10,000 Days	1,000 Days	Delta (%)	500 Days	Delta (%)	300 Days	Delta (%)	100 Days	Delta (%)
1	201.7	201.8	0.05	203.0	0.64	209.1	3.67	214.9	6.54
2	57.2	54.4	4.90	53.7	6.12	54.6	4.55	53.6	6.29
3	37.7	37.9	0.53	38.1	1.06	38.3	1.59	40.7	7.96
4	156.1	147.8	5.32	145.1	7.05	150.1	3.84	159.7	2.31
5	136.5	134.3	1.61	136.2	0.22	134.5	1.47	137.5	0.73
6	8.8	8.8	0.00	8.6	2.27	8.6	2.27	8.6	2.27
7	18.1	17.2	4.97	17.1	5.52	17.4	3.87	16.6	8.29
8	9.6	9.6	0.00	9.4	2.08	9.3	3.12	9.4	2.08
9	193.5	196.7	1.65	196.6	1.60	191.9	0.83	185.2	4.29
10	33	31.7	3.94	32.0	3.03	32.9	0.30	33.6	1.82
11	85	86.6	1.88	87.1	2.47	87.7	3.18	89.6	5.41
12	148.1	156	5.33	159.5	7.70	161	8.71	165.0	11.41
13	47.1	45.6	3.18	46.2	1.91	43.9	6.79	39.5	16.14
14	81.2	82.3	1.35	81.2	0.00	82	0.99	84.9	4.56
15	26.5	26.3	0.75	27.2	2.64	27.2	2.64	27.4	3.40
16	55.2	55.2	0.00	56.7	2.72	57.5	4.17	57.7	4.53
17	379.5	376.9	0.69	375.4	1.08	375.6	1.03	344.9	9.12
18	155.6	160.6	3.21	166.5	7.01	166.6	7.07	165.6	6.43
19	38.6	38.8	0.52	38.7	0.26	38.7	0.26	39.0	1.04
20	60.8	61.2	0.66	62.5	2.80	63.7	4.77	64.8	6.58
21	134.5	135.5	0.74	136.9	1.78	136.7	1.64	135.3	0.59
22	17.2	16.6	3.49	16.0	6.98	15.9	7.56	16.9	1.74
23	842.2	841.2	0.12	854.9	1.51	839.8	0.28	847.8	0.66
24	26.3	26.1	0.76	25.9	1.52	25.6	2.66	27.0	2.66
25	9.5	9.5	0.00	9.4	1.05	9.2	3.16	9.1	4.21
26	17	16.7	1.76	16.6	2.35	16.4	3.53	17.2	1.18
27	456.8	454	0.61	455.6	0.26	461.3	0.99	452.0	1.05
28	137.8	131.5	4.57	130.3	5.44	131.5	4.57	138.7	0.65
29	211.3	214.1	1.33	214.4	1.47	218.8	3.55	213.1	0.85
30	10.9	11	0.92	11.0	0.92	11.1	1.83	11.3	3.67
31	18.6	18.6	0.00	18.5	0.54	18	3.23	17.7	4.84
32	36.7	35.2	4.09	35.3	3.81	35.7	2.72	35.1	4.36
33	585.9	575.3	1.81	536.1	8.50	553.6	5.51	562.5	3.99

34	374	376.5	0.67	378.1	1.10	370.1	1.04	363.3	2.86
35	473.7	480.3	1.39	469.9	0.80	493.6	4.20	545.3	15.12
36	19	18.9	0.53	18.5	2.63	18	5.26	17.9	5.79
37	151.1	148.3	1.85	143.5	5.03	143	5.36	148.7	1.59
38	812.2	812.2	0.00	815.3	0.38	821.9	1.19	813.3	0.14
39	134.6	137.3	2.01	135.4	0.59	134.8	0.15	136.6	1.49
40	63.8	63.7	0.16	63.9	0.16	63.6	0.31	62.6	1.88
41	136.6	135.2	1.02	140.1	2.56	134	1.90	128.4	6.00
42	19.8	19.7	0.51	20.1	1.52	20.3	2.53	20.6	4.04
43	55.3	55.1	0.36	58.5	5.79	60.4	9.22	61.6	11.39
44	335.1	334.4	0.21	352.3	5.13	360.3	7.52	376.4	12.32
45	121.3	118.3	2.47	118.8	2.06	119.3	1.65	120.0	1.07
46	63.6	60	5.66	57.6	9.43	57.9	8.96	62.6	1.57
47	17.4	17.9	2.87	18.0	3.45	17.2	1.15	16.8	3.45
48	16.3	16.2	0.61	16.0	1.84	16.4	0.61	16.3	0.00
49	115.2	112.4	2.43	114.8	0.35	112.5	2.34	111.9	2.86
50	205.8	208.7	1.41	204.5	0.63	207.2	0.68	211.4	2.72
51	78.5	80.6	2.68	79.5	1.27	77.7	1.02	78.5	0.00
52	269.5	270.6	0.41	272.0	0.93	275.1	2.08	283.0	5.01
53	4.5	4.6	2.22	4.5	0.00	4.4	2.22	4.3	4.44
54	95.7	96.4	0.73	97.3	1.67	97.7	2.09	102.0	6.58
55	4	3.8	5.00	3.8	5.00	3.8	5.00	3.7	7.50
56	99.3	98.3	1.01	98.3	1.01	98.9	0.40	99.6	0.30
57	325	325.7	0.22	326.9	0.58	327.9	0.89	320.8	1.29
58	48.2	48.5	0.62	48.3	0.21	48	0.41	47.3	1.87
59	11.6	11.4	1.72	11.7	0.86	11.8	1.72	12.5	7.76
60	52.4	51.8	1.15	51.5	1.72	51.6	1.53	52.9	0.95
61	32.8	33.2	1.22	33.1	0.91	32.9	0.30	33.5	2.13
62	49.4	49.6	0.40	49.9	1.01	50.3	1.82	49.6	0.40
63	597.3	593	0.72	599.8	0.42	571.9	4.25	571.5	4.32
64	96	97	1.04	97.1	1.15	97.4	1.46	96.2	0.21
65	14.7	14.2	3.40	13.9	5.44	14.1	4.08	13.8	6.12
66	321	321.1	0.03	316.9	1.28	319.6	0.44	322.3	0.40
67	234.3	232.3	0.85	232.5	0.77	229.1	2.22	222.2	5.16
68	85.8	86.9	1.28	86.8	1.17	86.4	0.70	87.1	1.52
69	130.6	129.7	0.69	125.7	3.75	127.4	2.45	123.0	5.82
70	67.5	66.7	1.19	65.7	2.67	66.4	1.63	66.8	1.04
71	276.5	273	1.27	270.8	2.06	273.0	1.27	268.1	3.04
72	68.3	66.9	2.05	69.9	2.34	70.2	2.78	80.0	17.13
73	145.2	142.7	1.72	142.1	2.13	141.8	2.34	141.8	2.34
74	122.6	122.6	0.00	122.6	0.00	122.4	0.16	122.4	0.16
75	43.6	43.8	0.46	42.5	2.52	42.3	2.98	43.0	1.38
76	110.8	111.8	0.90	111.0	0.18	110.6	0.18	106.7	3.70

77	21.9	21.8	0.46	21.7	0.91	21.5	1.83	20.6	5.94
78	79.3	80.1	1.01	80.9	2.02	81.1	2.27	77.4	2.40
79	29.8	30	0.67	29.4	1.34	29.6	0.67	29.8	0.00
80	116.9	117.4	0.43	116.4	0.43	117.5	0.51	119.9	2.57
81	35.5	36.8	3.66	37.0	4.23	38.7	9.01	38.4	8.17
82	54.1	53.1	1.85	53.3	1.48	53.0	2.03	53.3	1.48
83	77.9	76.3	2.05	75.5	3.08	72.5	6.93	73.4	5.78
84	73.9	74.2	0.41	72.2	2.30	72.5	1.89	73.4	0.68
85	29.6	30.5	3.04	31.9	7.77	32.4	9.46	31.9	7.77
86	74.9	73	2.54	76.3	1.87	77.4	3.34	77.8	3.87
87	63.7	64.5	1.26	62.0	2.67	61.1	4.08	62.2	2.35
88	72.7	73.1	0.55	74.4	2.34	73.4	0.96	72.9	0.28
89	25.7	26	1.17	26.1	1.56	26.1	1.56	26.6	3.50
90	74.7	76.6	2.54	76.7	2.68	76.0	1.74	73.1	2.14
91	715.8	735.8	2.79	751.5	4.99	763.6	6.68	797.1	11.36
92	28.3	28.4	0.35	27.1	4.24	27.0	4.59	27.6	2.47
93	355.6	358.1	0.70	355.4	0.06	358.3	0.76	367.0	3.21
94	120.5	120.9	0.33	122.3	1.49	125.1	3.82	127.2	5.56
95	178.2	178.2	0.00	179.6	0.79	176.9	0.73	172.2	3.37
96	59.2	59.2	0.00	59.0	0.34	58.2	1.69	56.3	4.90
97	303.1	301.7	0.46	306.3	1.06	302.7	0.13	308.4	1.75
98	64.8	64.8	0.00	63.2	2.47	63.3	2.31	64.2	0.93
99	1130.6	1134.8	0.37	1116.6	1.24	1110.7	1.76	1159.6	2.57
100	63.4	63.4	0.00	62.9	0.79	61.5	3.00	62.8	0.95
			1.45		**2.31**		**2.79**		**3.91**

APPENDIX C

Results

			T-ATF and LHA1					
Case	**37**	**40**	**43**	**45**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	63,500	63,500	63,500	63,500				
Days	10,000	10,000	10,000	10,000				
Dyn Ten (kips)	175.6	59.1	55.7	127.9				
Case	**105**	**109**	**113**	**120**	**126**	**127**	**131**	**129**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	132.7	61.4	65.9	128.9	128.5	56.8	57.0	113.5
Case	**137**	**130**	**134**	**135**	**136**	**138**	**139**	**157**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	491.0	106.0	91.0	198.5	439.5	91.9	72.4	168.0
Case	**147**	**143**	**146**	**150**	**148**	**156**	**149**	**151**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	1,000	1,000	1,000	1,000
Dyn Ten (kips)	45.9	22.9	35.4	67.3	44.4	22.2	28.7	56.8
Case	**122**	**152**	**153**	**163**	**158**	**154**	**155**	**159**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	70.5	28.5	51.1	94.6	69.7	28.6	44.7	83.2

			T-ATF and LHA1					
Case	**56**	**60**	**62**	**64**	**160**	**165**	**176**	**162**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	10,000	10,000	10,000	10,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	99.3	52.4	49.4	96.0	93.6	47.2	45.1	93.4
Case	**23**	**27**	**29**	**34**	**38**	**57**		
Tow Spd (kts)	9	9	9	9	9	9		
Wind Spd (kts)	35	35	35	35	35	35		
Wave Heading	0	60	120	180	0	60		
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000		
Towline Type	w	w	w	w	w	w		
Mean Ten (lbs)	63,500	63,500	63,500	63,500	45,000	45,000		
Days	10,000	10,000	10,000	10,000	10,000	10,000		
Dyn Ten (kips)	800.8	439.0	211.5	372.3	786.9	313.8		
Case	**50**	**54**						
Tow Spd (kts)	5	5						
Wind Spd (kts)	35	35						
Wave Heading	0	60						
Tow Length (ft)	2,000	2,000						
Towline Type	w	w						
Mean Ten (lbs)	20,500	20,500						
Days	10,000	10,000						
Dyn Ten (kips)	218.5	96.3						
Case	**66**	**68**	**70**	**73**	**1**	**164**	**161**	**167**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	95,000	95,000	95,000	95,000	**50,000**	73,000	73,000	73,000
Days	10,000	10,000	10,000	10,000	10,000	1,000	1,000	1,000
Dyn Ten (kips)	365.1	85.6	67.5	145.2	201.7	76.6	67.5	143.7
Case	**75**	**77**	**79**	**82**	**166**	**168**	**169**	**175**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	10,000	10,000	10,000	10,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	43.6	21.9	29.8	54.1	44.1	21.5	30.9	58.2

			T-ATF and LHA1					
Case	**84**	**86**	**88**	**90**	**170**	**171**	**172**	**173**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	1,000	1,000	1,000	1,000
Dyn Ten (kips)	61.7	25.9	39.6	81.3	59.8	24.9	41.8	74.7
			ARS50 and LHA1					
Case	**291**	**332**	**333**	**338**	**247**	**254**	**260**	**261**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	167.5	74.4	99.8	194.2	148.0	67.5	72.3	150.6
Case	**367**	**368**	**369**	**370**	**209**	**276**	**277**	**286**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	1,000	500	500	500
Dyn Ten (kips)	2,577.8	388.4	147.8	296.2	1,075.7	126.1	108.5	266.2
Case	**363**	**376**	**385**	**375**	**379**	**377**	**384**	**380**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	54.7	24.1	53.1	86.8	51.3	23.2	39.4	70.6
Case	**382**	**389**	**386**	**391**	**387**	**399**	**392**	**393**
Tow Spd (kts)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	74.1	36.1	84.8	116.6	70.1	29.6	57.3	95.0

			ARS50 and LHA1					
Case	**94**	**96**	**98**	**102**	**141**	**144**	**302**	**315**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	10,000	10,000	10,000	1,000	1,000	1,000	500	500
Dyn Ten (kips)	120.5	59.2	64.8	134.8	115.0	52.3	60.3	118.7
Case	**103**	**104**	**108**	**106**	**361**	**320**	**322**	**331**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	1,000	1,000	1,000	1,000	500	500	500	500
Dyn Ten (kips)	708.0	106.3	92.8	207.9	487.2	93.6	83.9	184.8
Case	**110**	**119**	**115**	**114**	**394**	**402**	**396**	**395**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	1,000	1,000	1,000	1,000	500	500	500	500
Dyn Ten (kips)	51.9	21.7	33.2	63.4	52.1	21.1	34.3	56.2
Case	**116**	**123**	**128**	**121**	**398**	**406**	**400**	**401**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	95,000	95,000	95,000	95,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	70.6	25.3	46.8	80.6	73.0	25.4	46.3	79.4
			T-ATF and AE26					
Case	**334**	**344**	**354**	**355**	**342**	**343**	**341**	**346**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	125,000	125,000	125,000	125,000	109,000	109,000	109,000	109,000
Days	710	500	500	500	500	500	500	500
Dyn Ten (kips)	169.3	86.7	65.4	140.3	159.7	81.8	61.6	127.0

			T-ATF and AE26					
Case	**335**	**349**	**351**	**353**	**352**	**359**	**422**	**403**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	125,000	125,000	125,000	125,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	659.5	130.6	100.3	214.8	604.3	121.8	92.7	184.5
Case	**125**	**133**	**124**	**132**	**407**	**404**	**405**	**409**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	59.4	30.1	48.5	91.2	53.8	27.7	36.7	72.3
Case	**418**	**423**	**424**	**425**	**426**	**408**	**417**	**410**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	108.8	35.6	69.5	104.7	90.8	32.4	50.6	94.3
Case	**340**	**337**	**336**	**348**	**357**	**360**	**366**	**371**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	91.2	54.0	50.6	91.3	86.5	50.4	44.4	77.8
Case	**345**	**362**	**373**	**378**	**411**	**381**	**389**	**429**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	318.5	82.2	73.9	132.8	227.8	77.3	68.0	119.8

			T-ATF and AE26					
Case	**413**	**414**	**430**	**415**	**416**	**421**	**428**	**427**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	44.2	24.3	29.9	64.5	43.2	24.1	33.9	53.6
Case	**438**	**431**	**432**	**435**	**440**	**447**	**437**	**436**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	59.9	25.3	43.9	68.5	58.5	25.3	43.4	75.2
Case	**339**	**439**	**442**	**449**	**441**	**445**	**446**	**461**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	142,000	**143,000**	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	417.6	194.0	163.4	307.7	508.4	180.7	152.6	296.0
Case	**347**	**350**	**515**	**443**	**444**	**448**	**450**	**451**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	6,941.5	4,913.5	2,634.3	1,946.1	4,192.7	2,660.5	1,756.2	1,607.8
Case	**453**	**452**	**458**	**459**	**460**	**456**	**457**	**471**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	117.6	51.0	74.5	129.0	109.7	50.7	68.7	116.3

			T-ATF and AE26					
Case	**466**	**462**	**463**	**464**	**465**	**468**	**469**	**472**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	187.9	95.1	114.2	146.4	179.8	97.5	105.8	147.7
Case	**479**	**473**	**474**	**475**	**476**	**488**	**478**	**477**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	491.5	178.2	158.8	337.4	496.7	164.1	150.0	311.0
Case	**480**	**481**	**482**	**483**	**489**	**490**	**491**	**486**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	4,339.7	3,361.3	2,531.5	2,278.9	3,358.8	2,437.1	1,928.5	1,871.4
Case	**487**	**392**	**493**	**501**	**519**	**494**	**495**	**496**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	89.5	46.7	63.1	102.3	89.2	46.9	66.1	105.0
Case	**497**	**499**	**500**	**504**	**502**	**503**	**505**	**506**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	148.7	87.7	99.9	153.5	146.0	88.1	97.4	142.9

			ARS50 and AE26					
Case	**510**	**518**	**509**	**507**	**508**	**517**	**513**	**514**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	251.8	107.4	97.3	200.5	241.8	103.0	84.7	175.2
Case	**516**	**525**	**524**	**520**	**522**	**523**	**526**	**527**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,037.6	761.1	151.9	343.7	2,206.0	377.6	149.2	304.5
Case	**142**	**538**	**549**	**530**	**533**	**541**	**528**	**534**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	53.4	30.0	50.5	76.7	51.9	29.9	47.1	79.2
Case	**529**	**531**	**532**	**539**	**536**	**537**	**540**	**542**
Tow Spd (kts)	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	147,000	147,000	147,000	147,000	109,000	109,000	109,000	109,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	90.1	37.5	70.5	110.6	88.8	36.2	67.5	109.8
Case	**543**	**544**	**548**	**546**	**547**	**551**	**552**	**555**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	113.4	66.2	58.2	119.4	97.1	55.8	48.6	99.5

			ARS50 and AE26					
Case	**572**	**556**	**557**	**571**	**563**	**558**	**553**	**554**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	580.2	108.6	99.0	182.5	368.2	104.6	88.8	163.4
Case	**559**	**560**	**561**	**568**	**562**	**586**	**564**	**584**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	49.1	23.9	37.4	60.9	50.2	23.5	39.8	55.5
Case	**567**	**569**	**570**	**573**	**566**	**574**	**575**	**599**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	70,000	70,000	70,000	70,000	52,000	52,000	52,000	52,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	67.2	26.7	50.2	73.9	66.2	26.3	48.8	72.8
Case	**578**	**579**	**580**	**576**	**577**	**585**	**582**	**583**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	959.0	300.0	306.8	574.1	1,412.6	330.3	205.0	467.9
Case	**587**	**588**	**589**	**591**	**592**	**593**	**594**	**595**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	41,175.3	84,949.6	15,793.0	4,602.9	5,686.8	4,017.1	2,668.3	2,654.6

			ARS50 and AE26					
Case	**596**	**597**	**598**	**600**	**601**	**602**	**612**	**605**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	166.4	62.8	109.6	162.2	110.8	53.7	78.0	124.3
Case	**606**	**607**	**627**	**623**	**603**	**604**	**609**	**610**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	142,000	142,000	142,000	142,000	105,000	105,000	105,000	105,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	229.1	123.5	145.8	176.6	181.0	96.0	111.4	148.4
Case	**611**	**613**	**614**	**615**	**616**	**617**	**621**	**622**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,201.3	286.1	222.2	575.5	1,119.5	431.7	215.4	488.8
Case	**624**	**625**	**626**	**619**	**620**	**628**	**629**	**630**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	6,294.4	5,532.5	4,011.4	3,673.6	4,230.9	3,245.0	2,504.9	2,635.3
Case	**635**	**650**	**631**	**632**	**634**	**633**	**636**	**637**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	105.0	51.2	81.2	123.9	99.6	46.5	74.1	124.3

			ARS50 and AE26					
Case	**644**	**646**	**638**	**639**	**647**	**640**	**643**	**645**
Tow Spd (kts)	3	3	3	3	3	3	3	3
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	113,000	113,000	113,000	113,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	164.9	91.1	110.9	172.9	153.1	86.6	107.2	153.8
			T-ATF and CG47					
Case	**1294**	**1312**	**1313**	**1295**	**1299**	**1303**	**1306**	**1315**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	300	300	500	500	500	500	500
Dyn Ten (kips)	218.7	88.9	66.1	145.0	197.5	79.4	57.6	123.1
Case	**1311**	**1326**	**1332**	**1332**	**1331**	**1361**	**1359**	**1360**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	300	300	500	500	300	300
Dyn Ten (kips)	2,194.6	148.2	96.7	223.1	1,360.6	111.4	92.1	166.2
Case	**1304**	**1307**	**1316**	**1329**	**1338**	**1353**	**1364**	**1374**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	67.7	27.2	45.4	82.0	62.3	26.3	42.3	66.7
Case	**1296**	**1300**	**1308**	**1318**	**1323**	**1335**	**1344**	**1355**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	116.7	33.8	65.8	98.6	113.7	31.5	54.5	83.4

			T-ATF and CG47					
Case	**1292**	**1293**	**1305**	**1314**	**1327**	**1336**	**1350**	**1362**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	74.9	44.1	38.4	78.0	51.9	29.9	35.4	51.4
Case	**1297**	**1301**	**1309**	**1319**	**1324**	**1334**	**1345**	**1356**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	205.1	70.9	73.0	129.0	104.6	47.7	73.7	119.8
Case	**1298**	**1302**	**1310**	**1320**	**1325**	**1339**	**1346**	**1357**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	42.8	22.5	36.9	61.7	40.4	23.5	34.2	55.1
Case	**1317**	**1340**	**1366**	**1399**	**1404**	**1408**	**1417**	**1418**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	57.1	24.5	45.0	72.4	57.8	23.5	43.7	63.9
Case	**1321**	**1322**	**1328**	**1330**	**1337**	**1341**	**1342**	**1348**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	419.5	259.4	163.5	360.2	644.4	211.6	136.4	332.0

			T-ATF and CG47					
Case	**1347**	**1358**	**1371**	**1380**	**1367**	**1373**	**1378**	**1381**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	39,940.4	38,597.9	3,724.6	1,715.2	3,895.4	2,159.4	1,136.2	1,103.5
Case	**1343**	**1349**	**1352**	**1372**	**1375**	**1382**	**1405**	**1410**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	168.9	66.0	91.3	176.0	150.3	63.1	76.2	125.8
Case	**1351**	**1354**	**1363**	**1365**	**1387**	**1396**	**1403**	**1413**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	284.0	122.2	137.9	198.0	239.5	123.4	106.8	198.7
Case	**1368**	**1379**	**1384**	**1393**	**1400**	**1411**	**1424**	**1434**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	607.9	181.0	129.2	266.4	303.6	123.4	102.7	199.7
Case	**1369**	**1376**	**1385**	**1394**	**1401**	**1419**	**1425**	**1435**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	2,858.6	1,874.8	1,313.0	1,248.4	1,917.2	1,213.6	829.8	793.5

			T-ATF and CG47					
Case	**1370**	**1377**	**1386**	**1395**	**1402**	**1412**	**1426**	**1436**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	102.6	49.6	63.1	118.4	98.8	51.1	61.1	101.7
Case	**1388**	**1414**	**1415**	**1416**	**1438**	**1442**	**1443**	**1472**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	300	300	500	300	300	500
Dyn Ten (kips)	167.5	92.7	99.7	137.7	178.3	91.7	94.8	143.5
Case	**1392**	**1409**	**1420**	**1432**	**1444**	**1449**	**1465**	**1478**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	421.8	421.3	249.9	443.0	642.6	549.8	256.5	460.3
Case	**1383**	**1391**	**1397**	**1398**	**1427**	**1437**	**1455**	**1462**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	58,325.6	52,921.4	5,901.5	2,796.4	5,959.7	3,210.1	1,947.3	1,823.7
Case	**1421**	**1484**	**1503**	**1485**	**1452**	**1459**	**1468**	**1479**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	235.0	119.5	112.2	188.5	191.8	104.3	90.7	138.9

			T-ATF and CG47					
Case	**1422**	**1423**	**1431**	**1439**	**1440**	**1445**	**1447**	**1448**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	380.4	166.5	159.9	230.4	263.1	163.8	132.4	227.1
Case	**1428**	**1433**	**1441**	**1446**	**1451**	**1458**	**1464**	**1467**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	823.5	547.4	368.5	486.8	759.6	314.7	187.0	343.3
Case	**1453**	**1460**	**1469**	**1480**	**1454**	**1461**	**1470**	**1481**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	4,428.0	3,003.7	2,224.9	2,144.0	3,082.2	1,999.0	1,540.1	1,542.7
Case	**1456**	**1471**	**1482**	**1491**	**1450**	**1457**	**1463**	**1466**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	144.9	83.2	77.9	134.8	132.2	81.6	73.7	113.9
Case	**1389**	**1390**	**1406**	**1407**	**1429**	**1430**	**1475**	**1476**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	224.0	129.3	122.6	166.4	220.6	131.9	117.3	177.2

			ARS50 and CG47					
Case	**1473**	**1477**	**1486**	**1487**	**1488**	**1493**	**1500**	**1508**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	556.3	103.1	88.1	190.9	295.9	92.7	63.1	148.6
Case	**1474**	**1489**	**1494**	**1516**	**1537**	**1568**	**1576**	**1593**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	3,603.9	892.5	140.2	330.7	1,609.1	252.6	109.5	248.7
Case	**1483**	**1502**	**1509**	**1510**	**1540**	**1541**	**1542**	**1538**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	64.6	28.3	54.9	77.5	68.4	27.3	49.7	64.4
Case	**1490**	**1501**	**1519**	**1534**	**1525**	**1526**	**1533**	**1550**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	122,000	122,000	122,000	122,000	73,000	73,000	73,000	73,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	111.5	35.9	77.0	96.5	110.1	32.3	66.5	93.2
Case	**1492**	**1497**	**1506**	**1514**	**1498**	**1507**	**1515**	**1523**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	78.2	48.1	49.3	87.2	60.3	32.4	43.9	64.6

			ARS50 and CG47					
Case	**1495**	**1504**	**1512**	**1520**	**1496**	**1505**	**1513**	**1521**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	341.2	92.1	81.9	170.0	121.0	61.2	82.3	147.4
Case	**1517**	**1551**	**1571**	**1595**	**1527**	**1549**	**1557**	**1584**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	48.2	21.5	43.2	62.7	49.3	21.6	36.8	58.4
Case	**1511**	**1518**	**1524**	**1522**	**1529**	**1535**	**1558**	**1574**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,000	43,000	43,000	43,000	26,000	26,000	26,000	26,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	65.9	24.5	52.7	73.6	62.3	23.0	50.1	70.7
Case	**1528**	**1536**	**1559**	**1575**	**1532**	**1539**	**1543**	**1546**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,118.6	862.1	211.6	532.8	1,976.3	638.6	204.9	499.0
Case	**1544**	**1548**	**1556**	**1567**	**1547**	**1555**	**1562**	**1563**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	12,661.0	9,806.4	3,717.0	2,735.8	5,834.4	3,319.3	1,777.8	1,906.8

			ARS50 and CG47					
Case	**1569**	**1560**	**1587**	**1561**	**1552**	**1570**	**1573**	**1579**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	400	500	500	500	500	500	500
Dyn Ten (kips)	168.9	62.6	110.6	165.3	154.5	62.5	91.2	132.8
Case	**1564**	**1566**	**1572**	**1578**	**1577**	**1583**	**1596**	**1609**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	135,000	135,000	135,000	135,000	81,000	81,000	81,000	81,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	268.3	129.1	137.9	206.1	238.9	125.6	117.6	249.8
Case	**1600**	**1610**	**1631**	**1656**	**1585**	**1601**	**1611**	**1632**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,140.6	409.2	167.1	400.1	416.9	155.2	120.1	273.8
Case	**1586**	**1602**	**1612**	**1633**	**1582**	**1589**	**1592**	**1597**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	3,457.3	2,274.0	1,590.8	1,795.4	2,134.0	1,398.1	963.2	1,172.4
Case	**1590**	**1588**	**1614**	**1613**	**1594**	**1598**	**1603**	**1625**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	106.8	48.1	70.9	127.0	102.8	48.8	67.0	104.3

			ARS50 and CG47					
Case	**1604**	**1615**	**1622**	**1628**	**1605**	**1616**	**1623**	**1629**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	61,000	61,000	61,000	61,000	37,000	37,000	37,000	37,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	171.4	94.1	105.2	144.3	170.9	89.7	99.3	192.2
Case	**1621**	**1637**	**1649**	**1657**	**1630**	**1635**	**1642**	**1646**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,055.1	1,006.7	672.4	836.0	3,303.1	1,474.0	623.2	885.1
Case	**1599**	**1608**	**1617**	**1618**	**1620**	**1624**	**1627**	**1634**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	18,903.1	13,965.1	5,538.3	4,144.7	8,909.1	5,399.7	3,145.9	3,012.2
Case	**1626**	**1663**	**1658**	**1660**	**1651**	**1652**	**1665**	**1666**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	218.2	117.8	117.3	186.0	205.0	108.6	96.7	162.0
Case	**1640**	**1647**	**1669**	**1674**	**1641**	**1648**	**1662**	**1670**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	140,000	140,000	140,000	140,000	84,000	84,000	84,000	84,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	357.2	170.3	158.2	268.5	261.4	172.2	143.0	279.0

			ARS50 and CG47					
Case	**1638**	**1655**	**1667**	**1675**	**1639**	**1650**	**1661**	**1668**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	2,175.6	1,105.2	659.4	938.2	1,243.6	492.7	218.0	551.3
Case	**1636**	**1645**	**1653**	**1654**	**1664**	**1672**	**1671**	**1673**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	5,441.9	3,793.4	2,852.2	2,996.1	3,835.1	2,420.2	1,800.4	2,134.2
Case	**1581**	**1591**	**1606**	**1607**	**1619**	**1643**	**1644**	**1659**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	143.5	83.6	84.7	147.1	131.1	83.5	78.8	123.0
Case	**1499**	**1530**	**1531**	**1545**	**1553**	**1554**	**1565**	**1580**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	66,000	66,000	66,000	66,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	222.2	133.0	130.3	176.1	220.2	131.0	122.7	225.8
			T-ATF and FFG7					
Case	**174**	**145**	**177**	**180**	**179**	**178**	**185**	**203**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	175.6	77.2	76.1	170.6	173.9	71.9	63.2	160.5

			T-ATF and FFG7					
Case	**1110**	**1117**	**1124**	**1132**	**1095**	**1099**	**1102**	**1108**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	50,000	50,000	50,000	50,000	24,000	24,000	24,000	24,000
Days	300	300	300	300	300	300	300	300
Dyn Ten (kips)	118.9	58.5	44.5	115.9	62.9	33.7	55.3	103.9
Case	**181**	**182**	**188**	**183**	**184**	**186**	**187**	**192**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	703.1	138.9	75.1	274.0	1,334.8	124.8	72.6	277.8
Case	**1135**	**1143**	**1147**	**1150**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	300				
Dyn Ten (kips)	812.7	169.2	91.3	208.7				
Case	**189**	**193**	**190**	**191**	**194**	**202**	**195**	**196**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	1,000	2,333	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	53.1	30.4	58.8	109.3	53.8	28.3	54.6	101.0
Case	**1129**	**1182**	**1197**	**1245**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	300				
Dyn Ten (kips)	54.4	28.8	51.8	93.9				

			T-ATF and FFG7					
Case	**197**	**198**	**199**	**200**	**201**	**204**	**205**	**206**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	500	500	500	500	500	500	1,000	500
Dyn Ten (kips)	82.6	40.6	75.9	114.5	78.7	38.3	63.2	98.5
Case	**1156**	**1159**	**1164**	**1167**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	300				
Dyn Ten (kips)	76.4	35.3	72.6	90.7				
Case	**207**	**208**	**236**	**221**	**219**	**210**	**212**	**211**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	1,000	1,000	500	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	94.2	42.8	47.0	120.9	89.5	33.4	32.4	87.4
Case	**1172**	**1178**	**1183**	**1188**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	300	300	300				
Dyn Ten (kips)	55.3	14.8	32.2	57.5				
Case	**213**	**214**	**216**	**215**	**222**	**223**	**220**	**218**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Dyn Ten (kips)	374.9	80.1	66.1	184.3	209.7	68.4	75.4	183.0

			T-ATF and FFG7					
Case	**1192**	**1201**	**1205**	**1207**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	300	300	300				
Dyn Ten (kips)	121.4	27.4	46.4	169.3				
Case	**140**	**217**	**224**	**225**	**226**	**229**	**246**	**227**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	10,000	1,000	500	500	500	500	500	500
Dyn Ten (kips)	75.4	26.7	49.5	98.6	76.5	25.5	52.1	97.0
Case	**1213**	**1227**	**1238**	**1243**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	500	300	300				
Dyn Ten (kips)	65.6	21.6	45.4	71.5				
Case	**228**	**230**	**231**	**232**	**233**	**234**	**235**	**237**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	98.0	35.6	69.7	121.5	104.6	34.2	68.3	114.4
Case	**1211**	**1215**	**1220**	**1225**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	20	20	20	20				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	300	300	500				
Dyn Ten (kips)	94.0	30.7	51.7	112.4				

			T-ATF and FFG7					
Case	**238**	**239**	**240**	**245**	**241**	**242**	**243**	**244**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	431.9	468.4	219.0	415.2	582.0	344.0	147.5	383.9
Case	**1217**	**1230**	**1235**	**1239**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	500				
Dyn Ten (kips)	745.3	170.3	101.5	370.2				
Case	**248**	**642**	**252**	**253**	**251**	**249**	**258**	**250**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	8,834.7	8,286.0	2,198.5	1,937.4	4,649.9	2,565.9	1,276.1	1,388.4
Case	**1218**	**1231**	**1236**	**1240**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	500				
Dyn Ten (kips)	2,746.3	1,377.7	728.3	949.9				
Case	**256**	**257**	**259**	**651**	**255**	**262**	**263**	**265**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	160.9	64.4	106.2	241.8	146.2	57.1	92.3	203.8

			T-ATF and FFG7					
Case	**1222**	**1234**	**1246**	**1254**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	500	300				
Dyn Ten (kips)	131.1	53.5	84.3	134.4				
Case	**649**	**652**	**653**	**661**	**654**	**655**	**656**	**657**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	254.9	126.0	149.3	198.0	231.7	101.8	133.7	175.9
Case	**1232**	**1249**	**1252**	**1253**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	300	300	300				
Dyn Ten (kips)	230.6	101.9	118.5	274.8				
Case	**267**	**264**	**273**	**266**	**268**	**269**	**270**	**284**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	689.6	173.2	140.8	403.9	644.6	145.5	115.8	341.7
Case	**1244**	**1251**	**1258**	**1263**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	300	300	500				
Dyn Ten (kips)	157.1	38.3	58.7	176.3				

			T-ATF and FFG7					
Case	**271**	**274**	**275**	**272**	**278**	**279**	**285**	**280**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	3,429.2	2,244.3	1,446.0	1,563.6	2,558.6	1,607.7	1,098.2	1,243.9
Case	**1226**	**1233**	**1237**	**1262**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	300	300	500				
Dyn Ten (kips)	493.2	92.2	110.9	545.3				
Case	**662**	**669**	**659**	**660**	**663**	**668**	**664**	**665**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	155.9	47.3	77.0	173.4	140.7	46.8	83.1	152.2
Case	**1242**	**1250**	**1267**	**1268**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	300	300	300				
Dyn Ten (kips)	127.5	42.7	66.8	176.9				
Case	**667**	**670**	**671**	**678**	**672**	**673**	**674**	**675**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	233.3	96.5	118.0	218.0	235.5	90.9	118.8	205.5

			T-ATF and FFG7					
Case	**1247**	**1255**	**1273**	**1274**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	30	30	30	30				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	300	500	300				
Dyn Ten (kips)	218.5	85.6	91.3	235.1				
Case	**303**	**308**	**309**	**310**	**281**	**287**	**283**	**282**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	428.4	401.3	289.3	433.5	512.0	507.1	231.7	487.2
Case	**1248**	**1256**	**1269**	**1276**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	500	300	500	300				
Dyn Ten (kips)	1,035.2	474.9	194.1	497.0				
Case	**725**	**700**	**691**	**679**	**288**	**289**	**290**	**297**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	14,377.7	17,029.4	18,924.6	2,830.4	7,318.3	4,275.3	2,276.2	2,094.6
Case	**1257**	**1261**	**1270**	**1278**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	300	500	300	300				
Dyn Ten (kips)	3,753.1	2,011.8	1,233.2	1,618.3				

			T-ATF and FFG7					
Case	**680**	**681**	**683**	**682**	**685**	**686**	**690**	**705**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	277.3	84.8	121.8	249.1	222.6	80.0	96.7	228.2
Case	**1266**	**1289**	**1282**	**1286**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	500	500	300	500				
Dyn Ten (kips)	149.2	79.2	95.6	137.2				
Case	**684**	**688**	**687**	**689**	**693**	**704**	**695**	**716**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	515.5	160.0	161.1	241.2	319.8	141.3	145.7	200.2
Case	**1265**	**1272**	**1280**	**1281**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	50,000	50,000	50,000	50,000				
Days	500	300	300	300				
Dyn Ten (kips)	213.3	136.3	129.3	277.7				
Case	**292**	**293**	**294**	**295**	**299**	**296**	**298**	**313**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	714.7	548.3	408.3	591.5	931.4	508.9	360.5	577.6

			T-ATF and FFG7					
Case	**1264**	**1288**	**1290**	**1291**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	300	300	300				
Dyn Ten (kips)	226.3	52.5	68.7	266.1				
Case	**300**	**301**	**306**	**304**	**305**	**314**	**307**	**696**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	5,485.7	4,025.9	2,703.9	2,471.9	3,962.6	2,758.2	1,972.6	2,027.6
Case	**1224**	**1241**	**1259**	**1260**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	500	500	500				
Dyn Ten (kips)	767.2	170.5	153.4	642.1				
Case	**697**	**708**	**694**	**698**	**701**	**703**	**711**	**706**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	190.6	64.9	85.6	191.0	161.1	66.1	84.3	162.5
Case	**1284**	**1285**	**1277**	**1283**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	500	500	300	500				
Dyn Ten (kips)	142.7	57.3	77.1	169.4				

			T-ATF and FFG7					
Case	**707**	**702**	**709**	**710**	**712**	**717**	**728**	**714**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	243.5	124.5	151.6	233.6	233.4	123.0	141.9	222.4
Case	**1271**	**1275**	**1279**	**1287**				
Tow Spd (kts)	5	5	5	5				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	800	800	800	800				
Towline Type	f	f	f	f				
Mean Ten (lbs)	15,000	15,000	15,000	15,000				
Days	300	300	300	500				
Dyn Ten (kips)	262.2	106.9	116.4	279.7				
			ARS50 and FFG7					
Case	**715**	**718**	**719**	**729**	**112**	**118**	**111**	**117**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	500	500	500	500	10,000	10,000	10,000	10,000
Dyn Ten (kips)	248.1	99.3	117.7	215.9	222.1	91.9	95.0	207.1
Case	**720**	**721**	**722**	**732**	**733**	**734**	**730**	**731**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,790.0	233.2	111.0	314.8	1,381.7	269.8	89.8	299.7
Case	**726**	**727**	**735**	**736**	**737**	**745**	**738**	**739**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	50.0	38.1	67.3	126.2	49.7	34.4	62.1	108.4

			ARS50 and FFG7					
Case	**740**	**746**	**753**	**741**	**742**	**747**	**748**	**749**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	107,000	107,000	107,000	107,000	79,000	79,000	79,000	79,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	81.9	51.4	86.0	129.3	77.7	45.4	83.3	107.9
Case	**311**	**312**	**319**	**316**	**750**	**318**	**317**	**323**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	130.3	54.4	55.3	135.9	119.8	40.7	39.0	122.4
Case	**321**	**324**	**326**	**329**	**325**	**330**	**327**	**328**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	408.5	123.4	78.2	239.4	269.4	90.6	77.6	206.6
Case	**743**	**744**	**755**	**756**	**757**	**769**	**758**	**759**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	85.4	29.2	57.4	102.3	86.3	26.5	54.3	104.0
Case	**754**	**760**	**761**	**762**	**763**	**764**	**765**	**776**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	42,000	42,000	42,000	42,000	31,000	31,000	31,000	31,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	117.6	39.6	74.3	136.7	124.3	36.1	79.2	127.5

			ARS50 and FFG7					
Case	**766**	**770**	**780**	**773**	**788**	**767**	**768**	**771**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,178.9	1,008.0	255.9	664.4	2,040.8	953.7	241.7	692.4
Case	**772**	**785**	**781**	**777**	**774**	**775**	**792**	**782**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	11,628.1	15,647.6	4,188.6	2,681.3	7,382.5	5,682.8	2,355.0	2,035.1
Case	**793**	**778**	**779**	**807**	**799**	**783**	**784**	**789**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	154.0	63.0	111.4	271.5	153.5	63.5	105.2	202.8
Case	**790**	**791**	**794**	**795**	**796**	**804**	**797**	**798**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	133,000	133,000	133,000	133,000	98,000	98,000	98,000	98,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	225.5	112.2	146.8	215.1	233.2	113.5	148.4	191.9
Case	**801**	**802**	**803**	**805**	**806**	**808**	**809**	**810**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,447.1	374.5	192.9	670.6	1,053.4	255.9	151.1	534.2

			ARS50 and FFG7					
Case	**813**	**814**	**815**	**811**	**817**	**818**	**829**	**816**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	3,827.4	2,680.5	1,829.1	1,896.0	2,671.6	1,820.4	1,278.6	1,481.5
Case	**830**	**819**	**820**	**821**	**828**	**822**	**823**	**825**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	167.4	49.8	91.1	187.0	144.8	48.8	88.6	150.8
Case	**826**	**827**	**831**	**832**	**833**	**838**	**834**	**835**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	68,000	68,000	68,000	68,000	50,000	50,000	50,000	50,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	236.6	93.1	128.6	217.5	232.4	93.0	121.9	217.3
Case	**841**	**842**	**850**	**836**	**837**	**843**	**844**	**845**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,023.7	986.2	576.4	853.7	2,647.8	1,454.0	669.9	992.1
Case	**864**	**865**	**848**	**849**	**846**	**847**	**853**	**851**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	18,605.3	24,517.2	7,154.8	3,993.3	11,628.3	9,452.8	3,968.1	3,070.2

			ARS50 and FFG7					
Case	**852**	**856**	**854**	**855**	**879**	**866**	**857**	**858**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	265.1	83.1	123.7	257.2	264.7	87.4	110.4	239.7
Case	**861**	**880**	**871**	**859**	**860**	**867**	**868**	**869**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	143,000	143,000	143,000	143,000	106,000	106,000	106,000	106,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	449.6	151.7	159.8	246.3	300.2	143.7	163.9	219.0
Case	**870**	**872**	**873**	**874**	**876**	**875**	**877**	**878**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	2,386.7	1,232.5	716.0	1,250.4	1,988.7	907.8	551.0	1,019.4
Case	**881**	**886**	**883**	**901**	**882**	**884**	**889**	**900**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	500	500	500	500	500	500	300	500
Dyn Ten (kips)	6,168.0	5,065.7	3,317.0	3,265.3	4,366.1	3,248.9	2,295.2	2,467.7
Case	**902**	**885**	**887**	**888**	**891**	**890**	**898**	**894**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	300	500	300	300	300	300	300	300
Dyn Ten (kips)	197.7	65.2	92.1	211.9	161.5	67.3	93.6	162.0

			ARS50 and FFG7					
Case	**903**	**892**	**897**	**893**	**895**	**896**	**904**	**905**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	77,000	77,000	77,000	77,000	57,000	57,000	57,000	57,000
Days	300	300	300	300	300	300	500	500
Dyn Ten (kips)	246.0	127.6	155.3	245.0	228.7	123.9	143.5	234.7
			T-ATF and YRBM					
Case	**72**	**81**	**92**	**100**	**7**	**6**	**8**	**10**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Dyn Ten (kips)	87.5	35.5	28.3	63.4	23.6	8.8	9.6	37.9
Case	**372**	**906**	**907**	**908**	**910**	**909**	**911**	**913**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	320.3	83.5	63.2	129.7	63.9	18.3	16.1	73.2
Case	**916**	**914**	**915**	**917**	**13**	**24**	**15**	**16**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	500	300	300	300	10,000	10,000	10,000	10,000
Dyn Ten (kips)	62.1	34.5	33.2	61.8	58.3	26.3	26.5	55.2
Case	**918**	**921**	**934**	**935**	**936**	**919**	**920**	**937**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	300	300	500	500	300	300	500	500
Dyn Ten (kips)	140.1	57.7	49.1	97.2	73.3	38.3	38.4	93.5

			T-ATF and YRBM					
Case	**58**	**59**	**65**	**61**	**922**	**977**	**923**	**926**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	10,000	10,000	10,000	10,000	300	300	300	300
Dyn Ten (kips)	48.2	11.6	14.7	32.8	23.2	6.9	7.7	30.0
Case	**924**	**925**	**927**	**928**	**929**	**930**	**931**	**938**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	300	300	300	500	500	500
Dyn Ten (kips)	104.8	17.7	30.0	76.7	60.4	13.2	11.0	61.0
Case	**83**	**89**	**85**	**87**	**939**	**941**	**944**	**940**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	10,000	10,000	10,000	10,000	500	500	500	500
Dyn Ten (kips)	77.9	25.7	29.6	63.7	61.9	19.0	24.9	49.2
Case	**942**	**943**	**950**	**948**	**975**	**949**	**945**	**946**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	500	300	500	300	300	300
Dyn Ten (kips)	118.1	37.9	38.0	74.8	94.1	31.3	31.0	87.5
Case	**91**	**93**	**95**	**97**	**956**	**947**	**963**	**951**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	10,000	10,000	10,000	10,000	500	500	500	300
Dyn Ten (kips)	715.9	355.6	178.2	303.1	576.8	261.0	148.7	240.6

			T-ATF and YRBM					
Case	**952**	**953**	**976**	**961**	**954**	**955**	**960**	**962**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	300	500	300	500	500	500	500	500
Dyn Ten (kips)	2,291.7	1,244.7	697.1	970.3	1,861.8	941.6	568.6	838.4
Case	**957**	**958**	**959**	**964**	**965**	**966**	**978**	**967**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	300	300	300	300	300	300	500	500
Dyn Ten (kips)	149.0	96.2	81.1	110.7	131.8	101.1	81.3	116.7
Case	**972**	**980**	**968**	**969**	**970**	**971**	**979**	**989**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	500	500	500	300	300	300	500	500
Dyn Ten (kips)	208.0	218.9	146.6	191.3	212.5	211.0	136.3	183.0
Case	**63**	**67**	**69**	**71**	**981**	**982**	**983**	**984**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	10,000	10,000	10,000	10,000	500	500	500	500
Dyn Ten (kips)	597.3	234.3	130.6	276.5	384.9	140.7	102.4	198.7
Case	**985**	**1000**	**1028**	**986**	**987**	**988**	**994**	**1013**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	500	500	500	300	300	300	300	300
Dyn Ten (kips)	2,863.7	2,195.2	818.1	1,127.6	1,864.1	1,120.5	569.2	871.3

			T-ATF and YRBM					
Case	**74**	**76**	**78**	**80**	**1020**	**990**	**991**	**992**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	10,000	10,000	10,000	10,000	300	500	300	300
Dyn Ten (kips)	122.6	110.8	79.3	117.0	125.9	98.7	77.6	114.9
Case	**993**	**995**	**996**	**997**	**998**	**999**	**1005**	**1001**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	300	500	500	300	300	300	300	500
Dyn Ten (kips)	214.0	227.3	181.3	207.2	225.1	231.3	168.7	212.8
Case	**99**	**101**	**107**	**1002**	**1003**	**1004**	**1006**	**1007**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	10,000	1,000	1,000	300	300	300	500	500
Dyn Ten (kips)	1,130.6	574.7	404.5	561.7	958.6	446.4	324.2	473.7
Case				**33**				
Tow Spd (kts)				9				
Wind Spd (kts)				35				
Wave Heading				180				
Tow Length (ft)				2,000				
Towline Type				w				
Mean Ten (lbs)				63,500				
Days				10,000				
Dyn Ten (kips)				569.9				
Case	**4**	**3**	**2**	**5**	**26**	**31**	**36**	**42**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	10,636	10,636	10,636	10,636	7,500	7,500	7,500	7,500
Days	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Dyn Ten (kips)	204.3	38.6	55.9	144.7	15.8	17.9	20.8	20.2

			T-ATF and YRBM					
Case	**1008**	**1009**	**1010**	**1014**	**1011**	**1012**	**1015**	**1016**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	300	300	500	500	300	300
Dyn Ten (kips)	3,943.6	2,205.6	1,165.0	1,693.0	2,927.4	1,692.1	965.2	1,476.0
Case			**49**	**52**				
Tow Spd (kts)			9	9				
Wind Spd (kts)			35	35				
Wave Heading			120	180				
Tow Length (ft)			1,000	1,000				
Towline Type			w	w				
Mean Ten (lbs)			10,500	10,500				
Days			10,000	10,000				
Dyn Ten (kips)			114.4	258.5				
Case	**1017**	**1018**	**1019**	**1029**	**1021**	**1022**	**1030**	**1023**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	500	500	500	500	500	300	300
Dyn Ten (kips)	139.2	140.6	103.1	139.7	122.5	141.0	104.8	134.7
Case	**9**	**11**	**14**	**12**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,500	1,500	1,500	1,500				
Towline Type	f	f	f	f				
Mean Ten (lbs)	10,636	10,636	10,636	10,636				
Days	10,000	10,000	10,000	10,000				
Dyn Ten (kips)	219.9	80.3	81.8	141.2				
Case	**1024**	**1025**	**1032**	**1034**	**1035**	**1039**	**1031**	**1033**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	500	500	500	500	500	500
Dyn Ten (kips)	208.5	214.0	186.3	230.3	208.2	219.1	198.4	229.6

			T-ATF and YRBM					
Case	**1036**	**1037**	**1043**	**1071**	**1041**	**1038**	**1042**	**1040**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	500	500	500	500	300	300	300	500
Dyn Ten (kips)	3,097.8	1,191.5	520.7	717.4	1,693.4	559.9	404.6	597.3
Case	**53**	**55**						
Tow Spd (kts)	5	5						
Wind Spd (kts)	35	35						
Wave Heading	0	60						
Tow Length (ft)	2,000	2,000						
Towline Type	w	w						
Mean Ten (lbs)	2,500	2,500						
Days	10,000	10,000						
Dyn Ten (kips)	4.0	3.7						
Case	**1145**	**1118**	**1054**	**1044**	**1045**	**1119**	**1061**	**1046**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	500	500	300	500	300	300	300	300
Dyn Ten (kips)	99,999.9	99,999.9	6,299.8	2,605.2	8,260.0	99,999.9	1,746.6	2,153.5
Case	**1055**	**1048**	**1047**	**1062**	**1049**	**1053**	**1050**	**1052**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	300	300	500	300	500	300	500	300
Dyn Ten (kips)	136.2	143.8	106.7	145.6	121.3	130.1	112.3	138.1
Case	**1051**	**1056**	**1057**	**1058**	**1059**	**1060**	**1081**	**1070**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	500	500	500	300	300	300	300	300
Dyn Ten (kips)	209.8	208.0	231.0	230.7	209.1	208.1	224.7	234.7

			ARS50 and YRBM					
Case	**356**	**358**	**364**	**365**	**22**	**25**	**30**	**32**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,500	10,500	10,500	10,500
Days	500	500	500	500	10,000	10,000	10,000	10,000
Dyn Ten (kips)	72.1	40.5	28.4	75.1	22.9	9.5	10.9	36.7
Case	**641**	**374**	**383**	**390**	**46**	**47**	**48**	**51**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,500	10,500	10,500	10,500
Days	500	500	500	500	10,000	10,000	10,000	10,000
Dyn Ten (kips)	324.3	108.1	62.3	144.9	88.8	17.4	16.3	78.5
Case	**397**	**412**	**419**	**420**	**433**	**434**	**455**	**454**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	58.3	35.8	32.6	62.4	46.2	26.5	29.6	48.7
Case	**467**	**470**	**484**	**485**	**498**	**511**	**512**	**521**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	21,000	21,000	21,000	21,000	10,636	10,636	10,636	10,636
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	120.5	57.0	48.8	89.8	70.8	37.8	35.2	76.5
Case	**535**	**545**	**550**	**565**	**581**	**590**	**608**	**618**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	50.3	12.2	16.0	35.9	23.2	8.6	10.3	33.3

			ARS50 and YRBM					
Case	**648**	**658**	**666**	**676**	**677**	**692**	**699**	**713**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	102.9	19.6	24.7	78.0	64.9	12.5	12.0	65.9
Case	**723**	**724**	**751**	**752**	**786**	**787**	**800**	**812**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	79.2	26.2	30.9	55.5	64.3	22.4	27.2	55.9
Case	**824**	**839**	**840**	**862**	**863**	**899**	**912**	**932**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	20	20	20	20	20	20	20	20
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	11,000	11,000	11,000	11,000	8,500	8,500	8,500	8,500
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	115.7	40.7	42.4	75.6	96.0	33.1	33.6	80.9
Case	**933**	**973**	**974**	**1026**	**1027**	**1077**	**1078**	**1127**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	500	500	500	500	500	500	500	500
Dyn Ten (kips)	1,032.5	499.1	235.1	403.8	731.3	346.4	170.1	313.6
Case	**1128**	**1190**	**1191**	**1223**	**1209**	**1210**	**1228**	**1229**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	500	500	500	500	300	300	300	300
Dyn Ten (kips)	2,343.9	1,309.2	763.2	1,138.5	1,884.6	983.8	644.8	872.8

			ARS50 and YRBM					
Case	**1063**	**1064**	**1065**	**1066**	**1067**	**1084**	**1068**	**1069**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	500	500	300	300	300	300	500	500
Dyn Ten (kips)	144.4	95.9	85.4	115.8	139.6	95.3	83.1	114.1
Case	**1072**	**1073**	**1074**	**1075**	**1076**	**1080**	**1101**	**1079**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	43,500	43,500	43,500	43,500	35,000	35,000	35,000	35,000
Days	500	500	300	300	300	500	500	500
Dyn Ten (kips)	208.2	212.3	148.0	188.0	213.7	204.6	140.4	182.7
Case	**1086**	**1085**	**1082**	**1083**	**1087**	**1090**	**1093**	**1094**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	500	300	300	500	500	500	500	500
Dyn Ten (kips)	749.2	318.2	161.1	377.9	438.6	176.1	112.0	226.4
Case	**1092**	**1088**	**1089**	**1104**	**1096**	**1097**	**1098**	**1115**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	500	500	500	300	300	300	300	300
Dyn Ten (kips)	2,752.1	1,769.5	812.1	1,168.3	1,916.2	1,038.2	601.0	945.3
Case	**1114**	**1131**	**1091**	**1130**	**1100**	**1103**	**1109**	**1105**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	300	300	500	300	300	300	300	300
Dyn Ten (kips)	125.9	105.6	76.2	116.8	129.1	94.6	77.4	114.6

			ARS50 and YRBM					
Case	**1106**	**1112**	**1122**	**1137**	**1107**	**1113**	**1123**	**1138**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	30	30	30	30	30	30	30	30
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	32,500	32,500	32,500	32,500	26,000	26,000	26,000	26,000
Days	300	300	300	300	300	300	300	300
Dyn Ten (kips)	214.5	228.1	176.4	205.4	226.0	229.9	161.5	204.5
Case	**1111**	**1121**	**1136**	**1141**	**1125**	**1134**	**1149**	**1163**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	300	300	300	500	300	300
Dyn Ten (kips)	1,791.4	880.7	604.1	798.9	1,276.5	600.1	454.3	659.6
Case	**18**	**19**	**20**	**28**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	2,000	2,000	2,000	2,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	10,500	10,500	10,500	10,500				
Days	10,000	10,000	10,000	10,000				
Dyn Ten (kips)	211.5	39.1	59.3	137.4				
Case	**1116**	**1120**	**1126**	**1133**	**1139**	**1155**	**1175**	**1195**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	300	500	300	300	300	300
Dyn Ten (kips)	3,962.6	2,340.1	1,260.0	1,864.5	3,063.3	1,762.5	1,004.6	1,501.3
Case	**35**	**39**	**41**	**44**				
Tow Spd (kts)	9	9	9	9				
Wind Spd (kts)	35	35	35	35				
Wave Heading	0	60	120	180				
Tow Length (ft)	1,000	1,000	1,000	1,000				
Towline Type	w	w	w	w				
Mean Ten (lbs)	10,500	10,500	10,500	10,500				
Days	10,000	10,000	10,000	10,000				
Dyn Ten (kips)	560.5	125.8	150.3	397.9				

			ARS50 and YRBM					
Case	**1140**	**1144**	**1148**	**1151**	**1187**	**1196**	**1179**	**1194**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	300	300	300	300	300	500
Dyn Ten (kips)	138.7	134.6	107.4	140.4	122.6	138.0	102.7	138.5
Case	**1142**	**1153**	**1161**	**1169**	**1146**	**1154**	**1162**	**1170**
Tow Spd (kts)	9	9	9	9	9	9	9	9
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	51,500	51,500	51,500	51,500	41,000	41,000	41,000	41,000
Days	300	300	300	300	300	300	300	300
Dyn Ten (kips)	208.3	217.2	190.6	229.5	208.2	221.8	188.0	230.6
Case	**1152**	**1158**	**1166**	**1171**	**1157**	**1160**	**1165**	**1168**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	300	300	300	300	300	300	300	300
Dyn Ten (kips)	99,999.9	99,999.9	763.1	1,105.1	1,988.5	820.2	528.6	849.6
Case	**1173**	**1174**	**1181**	**1189**	**1180**	**1184**	**1198**	**1214**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Towline Type	w	w	w	w	w	w	w	w
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	300	100	300	300	300	300	300	300
Dyn Ten (kips)	40,248.2	99,999.9	2,864.5	2,707.4	6,243.8	99,999.9	1,759.1	2,181.3
Case	**1176**	**1185**	**1199**	**1203**	**1177**	**1186**	**1200**	**1204**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	300	300	500	300	300	300	500	300
Dyn Ten (kips)	135.9	147.3	109.9	138.6	122.0	131.1	109.4	136.8

			ARS50 and YRBM					
Case	**1193**	**1202**	**1206**	**1208**	**1219**	**1212**	**1216**	**1221**
Tow Spd (kts)	5	5	5	5	5	5	5	5
Wind Spd (kts)	35	35	35	35	35	35	35	35
Wave Heading	0	60	120	180	0	60	120	180
Tow Length (ft)	800	800	800	800	800	800	800	800
Towline Type	f	f	f	f	f	f	f	f
Mean Ten (lbs)	50,000	50,000	50,000	50,000	40,000	40,000	40,000	40,000
Days	500	300	300	300	300	300	300	300
Dyn Ten (kips)	209.2	208.0	224.1	231.5	210.1	208.8	223.7	235.0